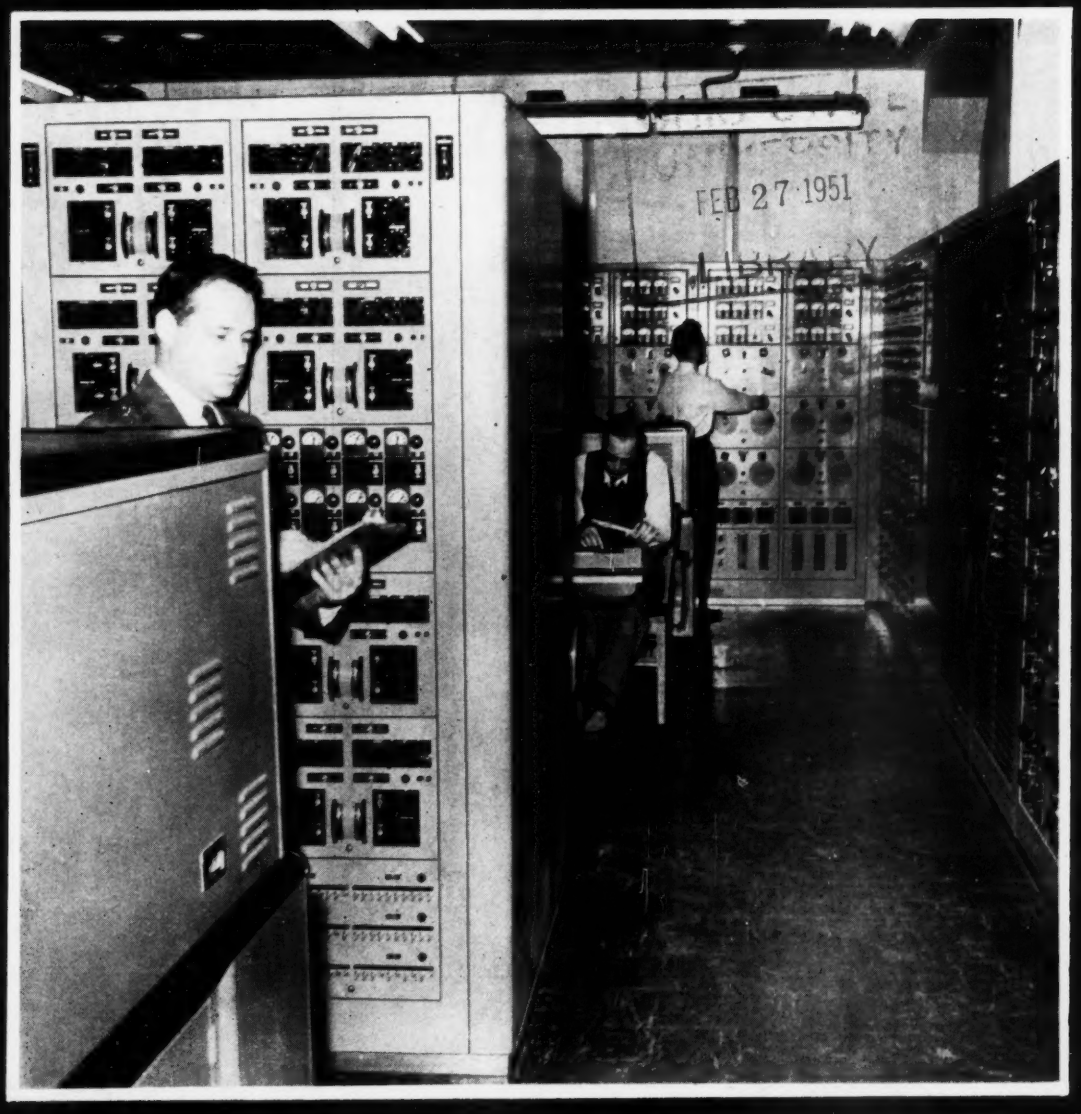
Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

Vol. 24 | FEBRUARY 1951 | No. 2

INCLUDING THE *Journal of the Instrument Society of America*

AND THE *Journal of the Southern California Meter Association*



A-c. Network Calculator at Texas A & M College solves complex operating and design problems in minutes or hours instead of weeks or months. ***(Courtesy Westinghouse Electric Corporation)***

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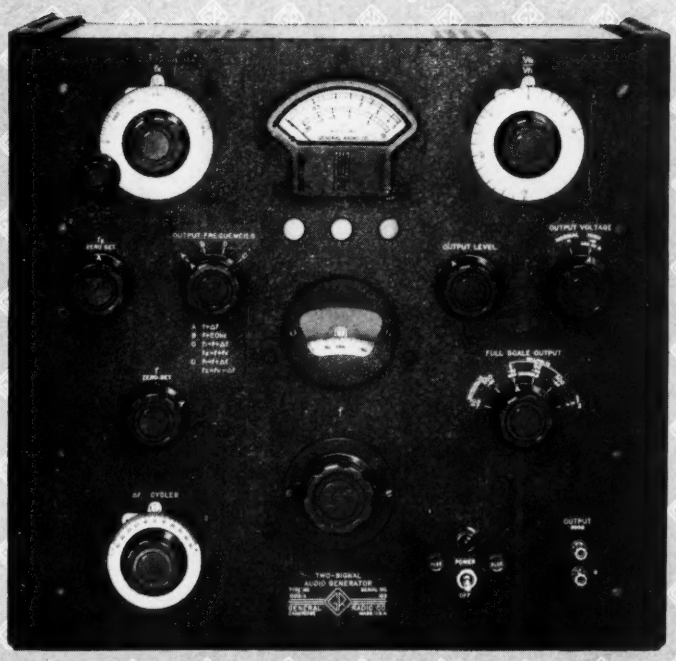

TYPE 1303-A
TWO-SIGNAL GENERATOR
$1050

a *New* Two-Signal Audio Generator

Ideal for Non-Linear Tests On: ☆ *Audio Amplifiers* ☆ *Hearing Aids* ☆ *Filter Networks* ★ *Noise Suppressors* ★ *High-Efficiency Speech Reproducing Systems* ★ *Loudspeakers* ☆ *F-M Systems with Pre-Emphasis* ★ *Recording Systems* ★ *Any System of Restricted Frequency Range*

The new G-R Type 1303-A Two-Signal Audio Generator supplies signals by the beat-frequency method. Three oscillators and three mixers are used to provide a number of output-signal combinations. The output of the mixers are combined in a linear adding network and then amplified through a very low-distortion power amplifier. The output from the amplifier is fed into a 600-ohm attenuator system, with a voltmeter to monitor the level at the input of the attenuator. The harmonic content and inter-modulation products in the final output are at a very low level. High stability of voltage and frequency are provided. The frequency drift from cold start is only a few cycles.

This A-F Signal Generator will supply the following signals:

- A single low-distortion sinusoidal voltage, adjustable in frequency from 20 cycles to 40 kilocycles, in two ranges.
- Two low-distortion sinusoidal voltages, each separately adjustable, one to 20 kc and the other to 10 kc.
- Two low-distortion sinusoidal voltages with fixed difference in frequency maintained between them as the frequency of one is varied. The fixed difference frequency is adjustable up to 10 kc, and the lower of the two frequencies is adjustable up to 20 kc.

The output is continuously adjustable and is calibrated both in volts and in db with respect to 1 mw into 600 ohms. The frequency calibration can be standardized within one cycle at any time. Its accuracy is ± (1% + 0.5 cycle).

This generator is an excellent and versatile signal source for the three standard non-linear distortion tests:

1. The widely used harmonic distortion test.

2. The intermodulation method that evaluates distortion in terms of the resultant modulation of a high-frequency tone by a low-frequency tone.

3. The difference-frequency intermodulation test, which evaluates distortion in terms of the amplitude of the difference-frequency components produced by intermodulation of two sinusoidal test signals of equal amplitude.

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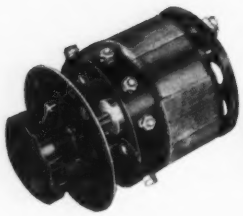
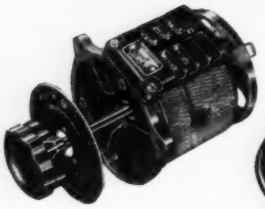
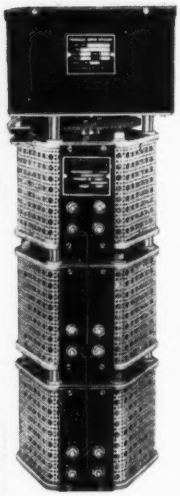


POWERSTAT
TYPE 20



POWERSTAT
TYPE 116U

POWERSTAT
TYPE 116



POWERSTAT
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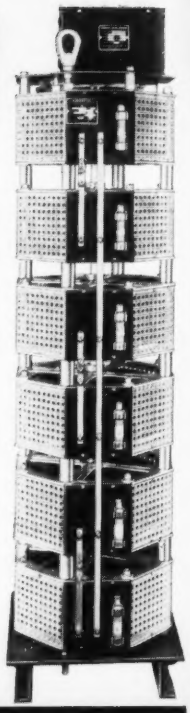

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POWERSTAT
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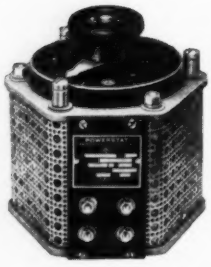

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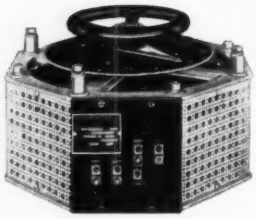
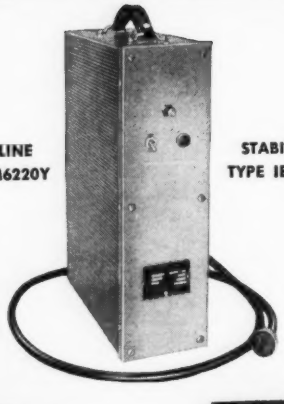


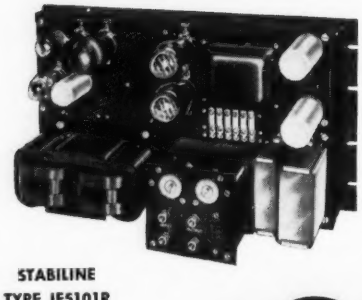
POWERSTAT
TYPE 1256

SE NE SOURCE FOR ALL

STABILINE
TYPE EM6220Y

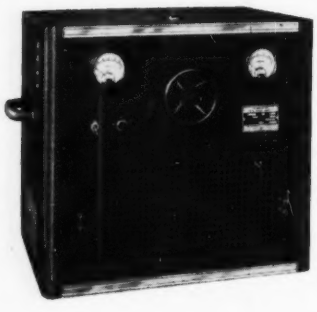


STABILINE
TYPE IE51005



STABILINE
TYPE IE5101R

STABILINE
TYPE EM4115



VARICELL
TYPE 13015

VOLTBOX
TYPE UC1M

POWERSTAT Variable Transformers

For variable a-c voltage control, a complete line of standard POWERSTAT variable transformers is available in air-cooled, oil-cooled and explosion-proof models for manual or motor-driven operation. They are the ideal source of continuously adjustable voltage from a-c power lines — featuring excellent regulation, high efficiency, conservative ratings, zero wave-form distortion, rugged mechanical construction, smooth control and easy mounting. The standard types are offered in 115, 230 and 460 volts, 25 and 50/60 cycles, single and three phase ratings in capacities from 405 VA to 100 KVA. For 400 cycles and higher frequency applications and for those requirements involving JAN specifications, there is a line of non-cataloged POWERSTAT variable transformers. Bulletin P550 describes in detail the complete line of standard POWERSTATS.

STABILINE Voltage Regulators

For maintaining constant output voltage from fluctuating a-c power lines STABILINE automatic voltage regulators are offered in two models — Type IE (Instantaneous Electronic) and Type EM (Electromechanical) to suit the needs of individual requirements. Type IE provides almost instantaneous correction . . . is completely electronic in action with no moving parts. Waveform distortion never exceeds 3%. Output voltage is held to within ± 0.1 percent of nominal for wide line variations; to within ± 0.15 percent of nominal for any load current change or load power factor change from lagging .5 to leading .9. Capacities range from 250 VA to 5 KVA. Type EM is ideal for those applications where zero waveform distortion, low cost and high efficiency is required but instantaneous correction is not essential. They feature insensitivity to magnitude and power factor of load and do not affect the system power factor. Numerous types are available in ratings to 100 KVA. Bulletin S351 fully describes both types of standard STABILINES. For information on STABILINES built to JAN requirements and for 400 cycle operation, send the engineering details of your application to Superior.

VOLTAGE CONTROL EQUIPMENT

VARICELL D-C POWER SUPPLIES

The VARICELL is the ideal source of low d-c voltages. It operates from an a-c power source to deliver a stabilized and regulated variable range of d-c voltages. Stabilization and regulation is ± 0.25 volts and R.M.S. ripple voltage never exceeds 0.1 volts. More engineering data in SECO form 2504.

VOLTBOX A-C POWER SUPPLIES

The VOLTBOX is a much needed instrument in the laboratory, inspection, test and plant maintenance departments. It is a compact, portable source of variable a-c voltage with all the necessary components in a lightweight case. Further information is found in Bulletin P550.

The Superior Electric complete line of voltage control equipment provides from one source apparatus to meet any and all requirements. With Superior equipment, you are assured of the highest quality and top electrical performance. If you are in doubt regarding your requirements, SECO engineers are in your territory to assist you. Meanwhile, use the coupon below to obtain complete information on any voltage control equipment in which you are interested.

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Instruments

Vol. 24 FEBRUARY 1951 No. 2

January Cover Explanation 177

TECHNICAL ARTICLES

Recording Motion of a Watch Balance Wheel by Watchcase Reaction 154
By Edward C. Lloyd

Construction and Calibration of a Laboratory Engine Pressure Indicator 156
By Gregory L. Laserson

Instrumentation of an Ammonia Plant 158
By Porter Hart and R. C. King

A High-pressure Differential Manometer 159
By Martin B. Biles

Question and Answer Session at Texas A&M's Symposium on "Instrumentation for the Process Industries" 160

THE MONTH'S NEW INSTRUMENTS 180

INSTRUMENTS ON THE MARCH

Improved Ramberg Vacuum-tube Accelerometer 198
Third Magnetic Observatory in Operation 200
Automatic Control Reduces Atomic-energy Plant Hazards 200

OTHER REGULAR FEATURES

Editorials 153, 203
Technical Societies 202
Education News 202
Manufacturers' Literature 234
Advertisers' Index 240

JOURNAL of the INSTRUMENT SOCIETY OF AMERICA 209

JOURNAL of the SOUTHERN CALIFORNIA METER ASSOCIATION

Rotameters 229
By W. J. Beckett
Industrial Applications of Manometers 231
By Charles Meriam

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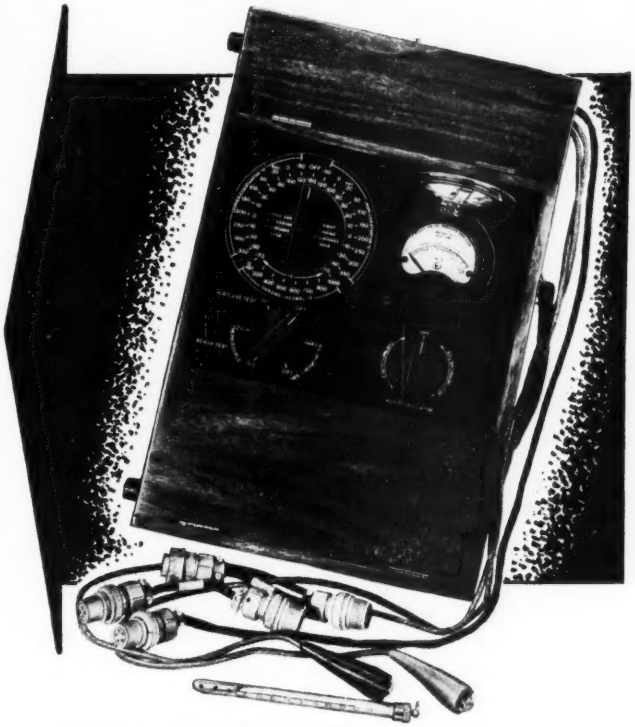

MODEL 81TT9 is provided with the following calibration ranges for Thermocouple Thermometers—0 to 1000°C chromel-alumel, minus 50 to plus 350°C iron-constantan and minus 50 to plus 350°C copper-constantan. Calibration points for ratiometers are provided for the following in centigrade —70, —50, —30, —10, 0, 10, 30, 50, 80, 100, 120 and 150, for dual or single indicators, in accordance with the AN-B-19 Curve.

MODEL 81TT5 is provided with calibration steps similar to the 81TT9, except that a range of zero to 600°F copper-constantan is substituted for the 0 to 1000°C chromel-alumel range, to provide means of checking this type of indicator found on some commercial aircraft.

Only a few simple operations are required to test temperature indicators with these instruments. Connect the indicator with the clip or plug leads, turn the resistance-voltage switch as required, adjust standardizing voltmeter to a red line by means of the rheostat and turn temperature selector switch. By comparing the indicator reading with the switch setting, the scale error of the indicator is determined.

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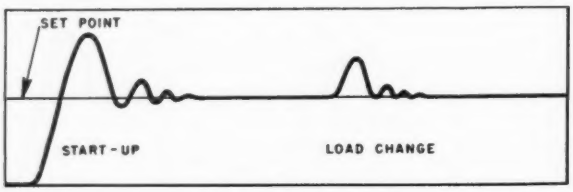
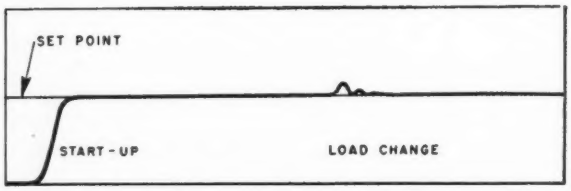


(A) Process curve obtained by Conventional Controller with Automatic Reset.



(B) Result produced by TRANSET TRI-ACT Controller under same conditions as "A".

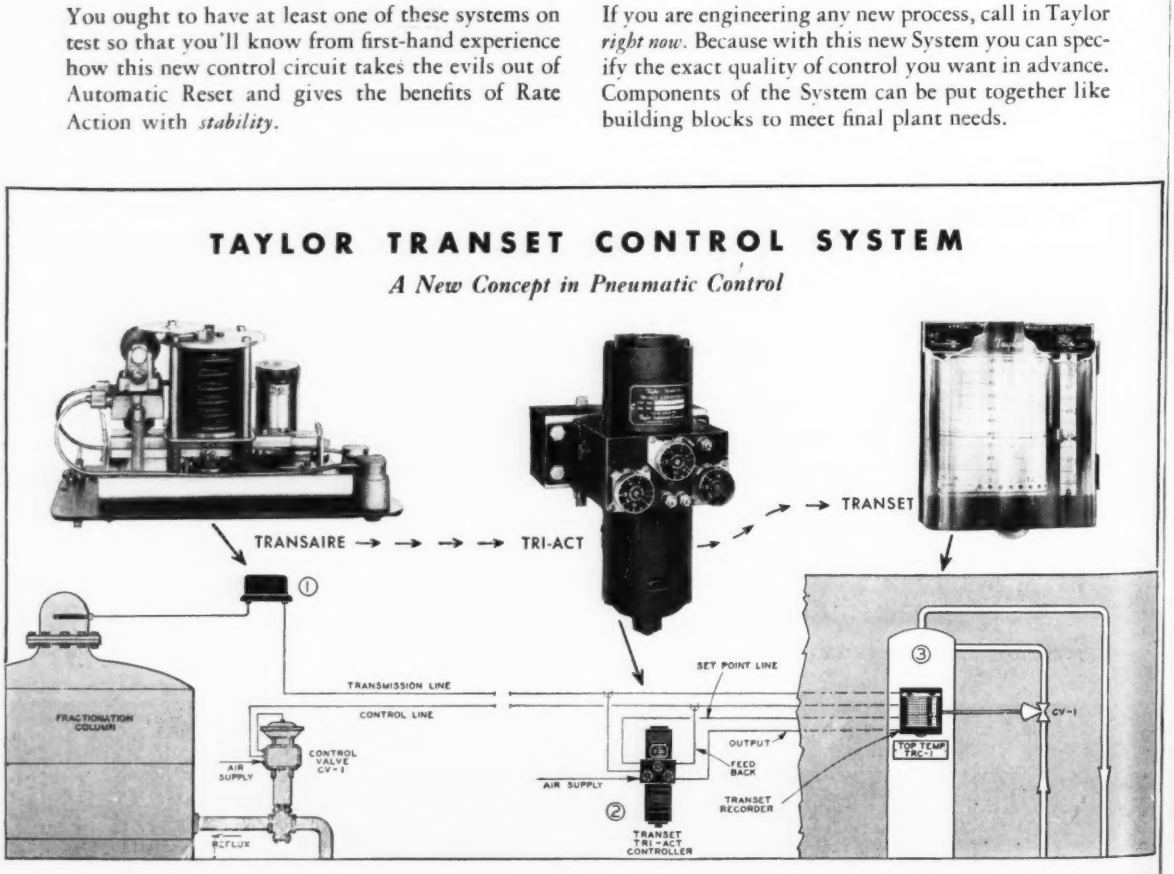
If you want to eliminate overpeaking on start-up . . . If you want to reduce the effect of load changes —

You ought to have at least one of these systems on test so that you'll know from first-hand experience how this new control circuit takes the evils out of Automatic Reset and gives the benefits of Rate Action with *stability*.

If you are engineering any new process, call in Taylor *right now*. Because with this new System you can specify the exact quality of control you want in advance. Components of the System can be put together like building blocks to meet final plant needs.

TAYLOR TRANSET CONTROL SYSTEM

A New Concept in Pneumatic Control



IN FOR THE NEW CONTROL SYSTEM

New Concept in Pneumatic Control is talk of Industry

NEARLY everyone in the industry is talking about the benefits of the new Taylor TRANSET Control System. Orders are literally pouring into Rochester. This new concept in pneumatic control, which gives unbelievably close control under adverse operating conditions, is a great contribution to all process industries. In almost any process, it will result in a higher yield of top quality product at lower cost.

The Taylor TRANSET Control System combines: **(1)** TRANSAIRE*, the force-balance temperature or pressure transmitters which have created new standards in measuring dynamic, or changing, temperatures and pressures. (The System works equally well with all types of transmitters.) **(2)** TRI-ACT*, the Controller which combines a wider range of response adjustments, an increased capacity relay air valve, and a new control circuit, to take advantage of the faster measuring systems. Can be locally or panel mounted. **(3)** TRANSET Recording Receiver, fits 3⅞″ x 4½″ panel opening, gives continuous 30-day chart record with 3 hours visible—especially adaptable to graphic panels. Other equally important features are: remote settings of control point, automatic-to-manual control, and instant check on controller performance and control valve position. Also available as an indicator.

Ask your Taylor Field Engineer or write to Taylor Instrument Companies, Rochester, N.Y., or Toronto, Canada. *Instruments for indicating, recording and controlling temperature, pressure, humidity, flow and liquid level.*

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5—*Faster Recovery On Load Changes*
6—*30-Day Chart Record On 4⅜″ x 5″ Panel Space*
7—*Permits Specifying Instrumentation Before Finalizing Process Design Details.*

SEND FOR:

ASME Paper #50-A-100. It tells the theory of TRI-ACT Control.

Taylor Bulletin 98097. It gives details of design and construction.

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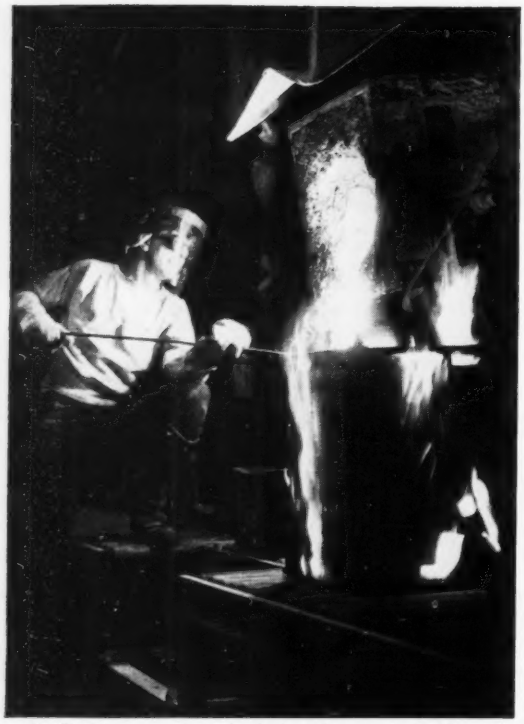

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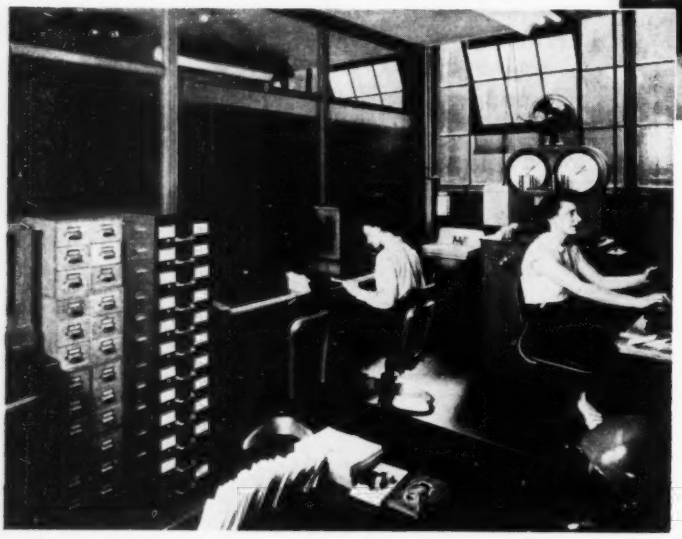

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(Alnico and other types)

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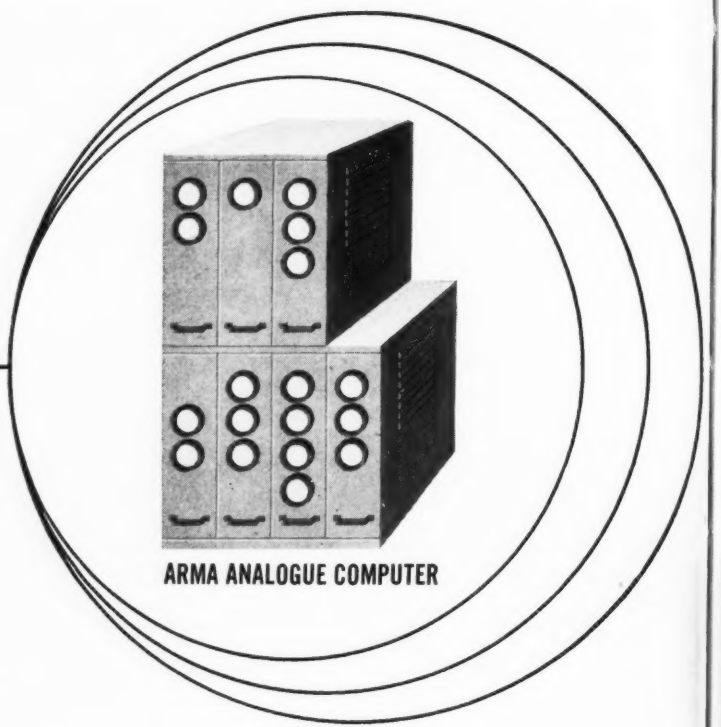

ARMA ANALOGUE COMPUTER

The *Analogue Computer* has long held a high place in Arma's work in such specialized fields as automatic gun-laying and torpedo-data computing for the U.S. Navy. Its present wider application to the needs of the other Services stems largely from accelerated post-war engineering at Arma, which resulted in miniaturizing its components and at the same time making them interchangeable and more accurate.

By this Arma development, the *Analogue Computer* has reached a new level of importance as a contributing factor in the high accuracy of American arms. It is typical of many things developed by Arma engineers to aid in making America safe against those who wish to destroy it.

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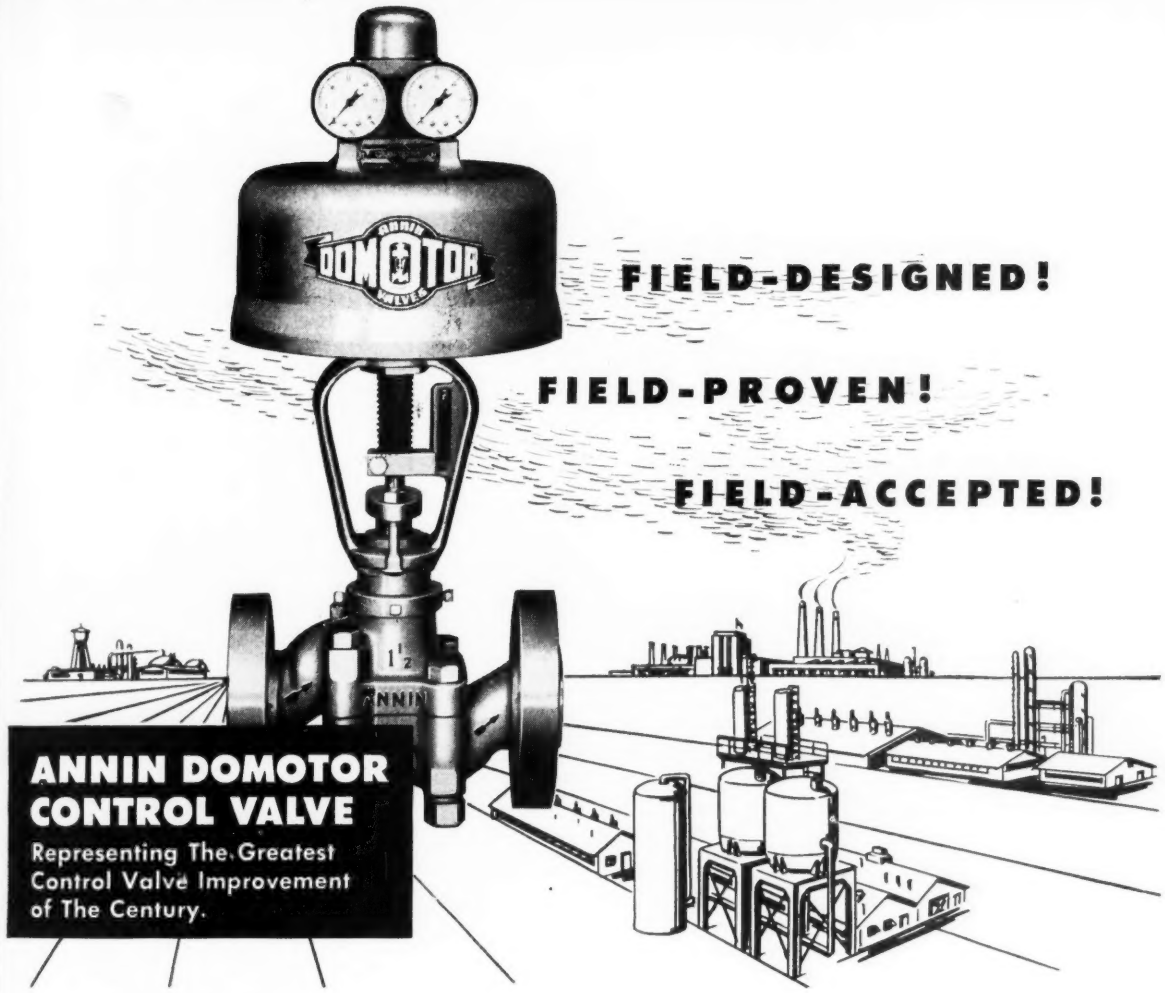

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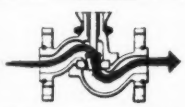

SINGLE SEAT — provides tight shut-off and precision control.

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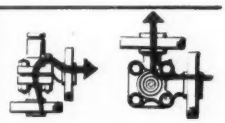
INTERCHANGEABLE FLANGES — increase flexibility, reduce inventories.

SMOOTH, POSITIVE ACTION — BOTH WAYS! Gives precision fluid control, greater stability.



DIRECTIONAL FLEXIBILITY — provides even greater application flexibility without additional cost.

ANNIN DOMOTOR VALVES

THE ANNIN COMPANY 3500 UNION PACIFIC AVE., LOS ANGELES 23, CALIF.

NOW

the MULTIPOINT CAPACILOG

easy to read...
to operate...
to service...

instrumentality...with si

The Multipoint Capacilog, embodying the latest features of Wheelco Instru*mentality*, is a Multipoint Direct Deflection Type Strip Chart Recorder giving up to six variable recordings on one chart. Used with furnaces, ovens, kilns, and other processing equipment, the Multipoint Capacilog gives a permanent record of temperature, speed, and other electrically measurable variables.

Easy to read because of a simple numbering system for instant identification of the different curves—plus direct reading of variables on a stationary scale.

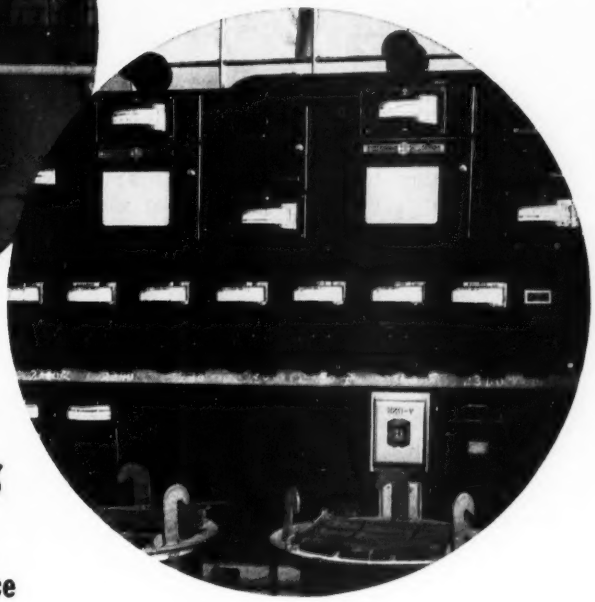
Easy to operate because the Electronic Link—Wheelco Instru*mentality*—brings recording down to its simplest form.

Easy to service because the Multipoint has fewer moving parts, simple interchangeability of components with all working parts quickly and easily accessible.

Write for Bulletin **MPC-1 on the new MULTIPOINT CAPACILOG—the latest addition to the WHEELCO CAPACILOG SERIES. Remember—when you specify WHEELCO, you get instrumentality. Wheelco Instruments Company, 833 W. Harrison Street, Chicago 7, Illinois**

wheelco

At Buckley Brothers—Petroleum Terminal—In their new $10 million bulk petroleum terminal the Connecticut company selected single point CAPACILOGS to control and record the temperatures in two huge storage tanks with an 8 million gallon capacity.



six memories

THE CAPACILOG IN ACTION...for service

Simplicity of operation and construction . . . low maintenance cost . . . ease of access for internal inspection; all add up to uninterrupted, reliable and economic service—a leading reason why more and more manufacturers in the various process industries are specifying the Wheelco Capacilog.

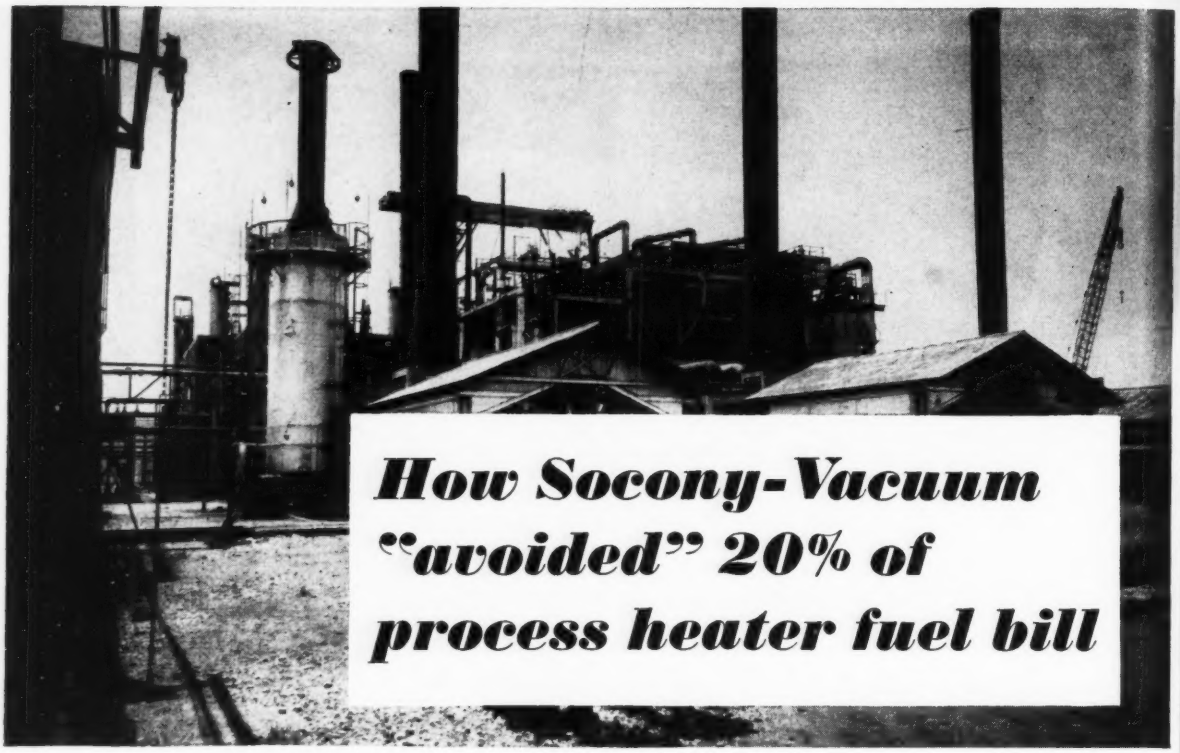
THE WHEELCO SINGLE POINT CAPACILOG is a direct reading, deflection type, strip chart recorder which gives you measurement, indication and control with a permanent record of electrically measurable factors.

At Armstrong Blum Company—Heat Treating and Normalizing—This well known manufacturer of hack saw blades and machines uses single point CAPACILOGS for controlling and recording temperatures to assure a maximum of product uniformity.

important

Wheelco single point Capacilogs are now available for delivery within four to five weeks from receipt of your order. Consult your local Wheelco representative for details.

electronic controls



How Socony-Vacuum "avoided" 20% of process heater fuel bill

program

When engineers at Socony-Vacuum, Trenton, Michigan refinery developed a complete fuel conservation program, process heaters came under close scrutiny. Socony-Vacuum engineers felt they could reduce the total cost of fuel used in raising the temperature of petroleum stock if they could keep the amount of excess air in the flue gases at a minimum.

need

Socony's instrument engineers wanted an instrument which would indicate excess air, so that they could make adjustments to keep the air at a minimum and thus save fuel.

specifications for instrument

must provide a **continuous indication** so that changes could be spotted immediately.

must **not be affected by changes in fuel composition** since different fuels are used in the heater furnaces.

must not **be affected by the presence of Hydrogen** in the gas sample.

preferably, measurement should have **direct relationship to excess air.**

selected

four HAYS MAGNO-THERM OXYGEN ANALYZERS and two HAYS 2-PEN ELECTRONIC RECORDERS

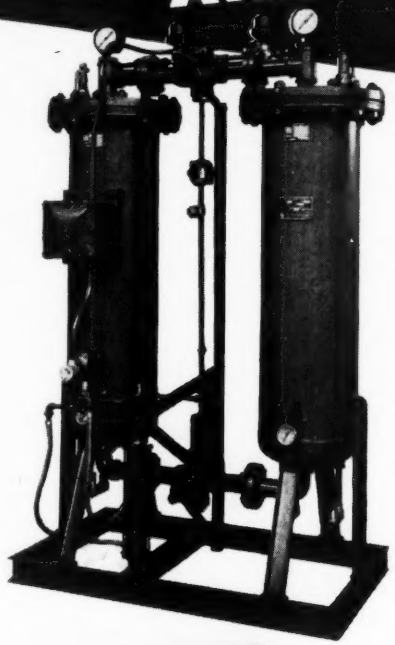
results

The entire fuel conservation program brought a 20% reduction in Socony's annual fuel bill. The Hays Oxygen Recorders have proved an effective combustion guide on the process heaters.

Improvement in the efficiency of your process heaters can mean large fuel savings. Write for Bulletin 50-829, 16 pages of information on how the O_2 meter works, where it's used, etc. No obligation.

THE **HAYS** CORPORATION *MICHIGAN CITY 8, INDIANA*

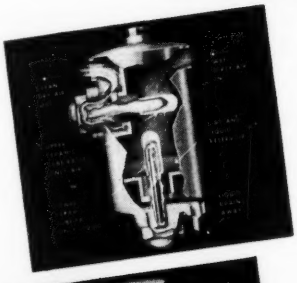
POSITIVE CONDITIONING OF INSTRUMENT AIR AND OTHER GASES



SELAS DEHYDRATOR

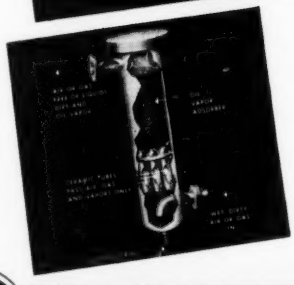
assures clean, moisture-free instrument air or other gases . . . for greater instrument accuracy, continuity of operations and with less maintenance. Adsorbs all moisture in the stream to extremely low dewpoint.

Many types of Selas Dehydrators—manual, semi-automatic and fully automatic—are available for all types of industries and operating conditions . . . readily reactivated at 300—350°F. utilizing steam, electricity or gas. Available as complete coordinated units of compressor, aftercooler, receiver and Dehydrator . . . or the Dehydrator separately.



SELAS *LIQUI-JECTOR*

Designed for automatic and continuous removal of water, oil, water-oil emulsions and dirt from compressed air and gas lines. No moving parts. Removes particles even finer than 100 microns in diameter . . . processes from 10 to 500 cfm. Separation is achieved by ceramic filters...requires minimum of maintenance.



SELAS *VAPE-SORBER*

Removes all traces of petroleum vapors—also water, oil, water-oil emulsions and dirt. This equipment adsorbs effectively all petroleum vapors present in compressed air or gas and provides clean supply for instrument, or other critical operation. Vapor adsorber is readily replaced when exhausted.

SELAS CORPORATION OF AMERICA
Philadelphia 34, Pennsylvania

Please send me latest bulletin on:

☐ Dehydrator ☐ Liqui-jector ☐ Vape-Sorber

Name ..... *Title* .....

Company .....

Address .....

SELAS

SELAS
CORPORATION OF AMERICA
PHILADELPHIA 34, PENNSYLVANIA

FOR QUICK, EASY and DEPENDABLE TEMPERATURE SETTINGS... the NEW LESLIE Calibrated Dial is the Answer!

THE new **CALIBRATED DIAL** now available on Leslie Class T and Class M type Temperature Regulators provides quick, easy, and dependable temperature settings. A simple turn of the dial to the temperature desired is all that is needed.

This calibrated dial adds the following features to those which already make Leslie Temperature Regulators a great value:

★ **TIME SAVING**—*Just turn the dial to desired setting—no need to wait for equipment to heat up to find out if setting is correct.*

★ **SAFE**—*Avoids costly overheating caused by guess setting.*

★ **RUGGED**—*Designed for production line use where frequent dependable readjustments are necessary for process work.*

★ **SIMPLE**—*Fits in place of standard adjusting sleeve. No complicated linkages or gages to go out of order or add friction.*

Calibrated Dials are easily installed on Class T and Class M Regulators already in service.

LESLIE engineers are available by phone, mail or personal calls to give recommendations on your temperature regulation problems.

SEND FOR—copy of
Temperature Regulator Bulletin No. 464B

LESLIE Temperature Regulator
Class MCC—1 *(with Calibrated Dial)*

50th Anniversary 1900–1950

Lowest Overall Cost per Operating Year

Look for LESLIE REGULATORS under "Valves" or "Regulators" in your classified telephone directory in the following cities where LESLIE factory trained engineers are located:

Albany, N. Y.	Buffalo, N. Y.	Greensboro, N. C.	Milwaukee, Wis.	Pittsburgh, Pa.	Savannah, Ga.
Albuquerque, N. M.	Chicago, Ill.	Greenville, S.C.	Minneapolis, Minn.	Ponca City, Okla.	Seattle, Wash.
Atlanta, Ga.	Cincinnati, Ohio	Houston, Texas	Mobile, Ala.	Portland, Ore.	St. Louis, Mo.
Baltimore, Md.	Cleveland, Ohio	Kansas City, Mo.	Monroe, La.	Providence, R. I.	Syracuse, N. Y.
Beaumont, Tex.	Denver, Colo.	Kingsport, Tenn.	New Orleans, La.	Richmond, Va.	Tucson, Ariz.
Birmingham, Ala.	Des Moines, Iowa.	Los Angeles, Calif.	New York, N. Y.	Rochester, N. Y.	Wilkes-Barre, Pa.
Boston, Mass.	Detroit, Mich.	Louisville, Ky.	Orlando, Fla.	Rutherford, N. J.	Wilmington, Calif.
Bridgeport, Conn.	Duluth, Minn.	Memphis, Tenn.	Philadelphia, Pa.	San Francisco, Calif.	Youngstown, Ohio

Montreal, Que., Can. Toronto, Ont., Can. Vancouver, B.C., Can. Bruxelles-Forest, Belgium

718

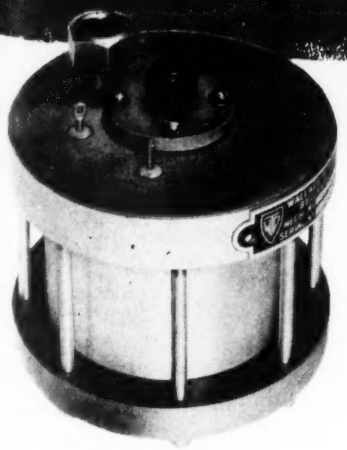
ESTABLISHED 1900
LESLIE CO.

299 Grant Avenue, Lyndhurst, New Jersey

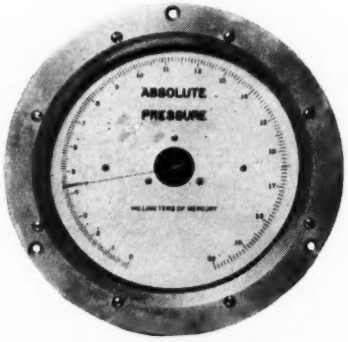
FLOATLESS LEVEL CONTROLS • PRESSURE REDUCING VALVES • PRESSURE CONTROLLERS
SELF CLEANING STRAINERS • PUMP GOVERNORS • TEMPERATURE REGULATORS
• AIR HORNS • STEAM WHISTLES

FOR DEEP VACUUM OPERATIONS

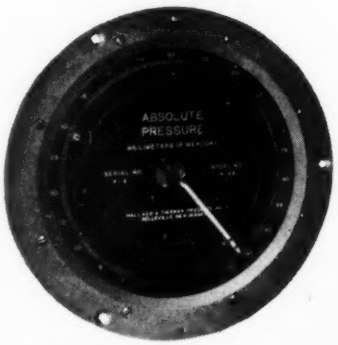
W&T PRECISION INSTRUMENTS



FA-193



FA-160 0-20 Scale



0-100 Scale

A-85

THE W&T ABSOLUTE PRESSURE CONTACTOR

This sensitive, yet durable aneroid device is used for actuating an electric circuit at a preset value of absolute pressure.

Outstanding features of the Contactor, type FA-193, include:

Range of adjustment	0-2 mm Hg. and other ranges made to customer's specifications up to 800 mm Hg. absolute pressure.
Sensitivity	will make or break within 0.10 mm Hg
Contact capacity	5 ma at 115 volts A.C.
Repeatability	0.10 mm Hg.
Vacuum-tight construction	
Over pressure protection	

THE W&T ABSOLUTE PRESSURE INDICATOR

This precision instrument is used for quick, dependable indications of absolute pressures in the vacuum range. Pressure readings are independent of the nature of the gas. It is available in two dial sizes — 2¾" and 6".

Other features of the Indicator, type FA-160, include:

Range	0-20, 0-50, 0-100, 0-200, 0-410 and 390-800 mm Hg. absolute pressure.
Sensitivity	One part in 500
Accuracy	One part in 300
Over pressure protection	
Direct readings	
Rugged vacuum-tight construction	

THE W&T ABSOLUTE PRESSURE CONTROLLER

The Controller with its associated Electronic Relay furnishes precision control of absolute pressure and provides a continuous indication of absolute pressure. Independent adjustment of the "high" and "low" contacts is made through a magnetic clutch thus eliminating stuffing boxes and seals and ensuring leak-tight operations.

Outstanding features of the Controller include:

Range	0-20, 0-50, 0-100, 0-200, 0-410 and 390-800 mm Hg. absolute pressure.
Sensitivity	One part in 500
Accuracy	One part in 300
Relay contact capacity	5 amps, 110 Volts, 60 cycles non inductive load.
Fast accurate response	
Over pressure protection	
Vacuum-tight construction	

Additional Information Will Be Supplied On Request

WALLACE & TIERNAN
PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities

Here's How to Erase Smoke Troubles

VIOLATION OF SMOKE ORDINANCE

LOSS OF FUEL ECONOMY

BAD COMMUNITY RELATIONS

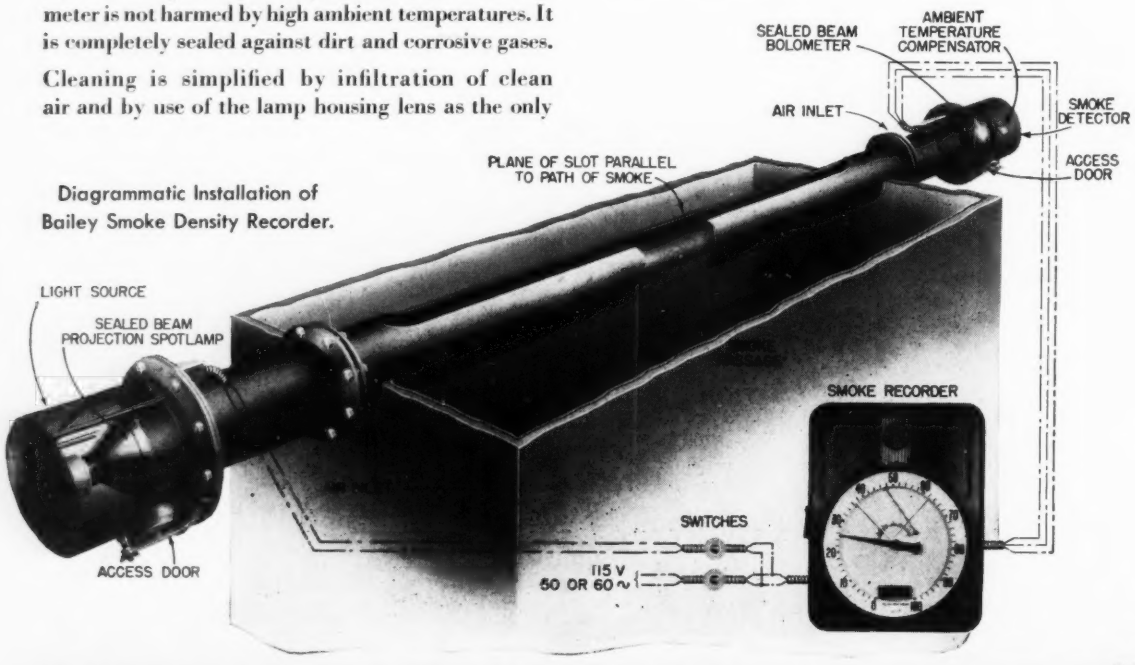
★ One of your first steps in erasing these troubles which result from excessive smoke, should be the installation of a Bailey Smoke Density Recorder. This 24-hour recorder is not an ordinary photo-cell instrument. Instead it detects smoke density by a Bolometer which is simply a sturdy tungsten filament and a parabolic mirror, mounted in a standard sealed beam automobile head lamp housing.

In using this simple, unique smoke detector, you do not have to provide cooling devices since the Bolometer is not harmed by high ambient temperatures. It is completely sealed against dirt and corrosive gases.

Cleaning is simplified by infiltration of clean air and by use of the lamp housing lens as the only window between the Bolometer and the gas passage.

It's easy to secure and maintain alignment of the sealed beam light source with the Bolometer since they are mounted at opposite ends of a slotted pipe which extends across the smoke passage.

For complete information on how you can profitably use this unique instrument to erase your smoke troubles, ask for Bulletin 211, "Bailey Smoke Density Recorder".



Diagrammatic Installation of Bailey Smoke Density Recorder.

G-29

BAILEY METER COMPANY

1041 IVANHOE ROAD, CLEVELAND 10, OHIO • BRANCH OFFICES IN PRINCIPAL CITIES

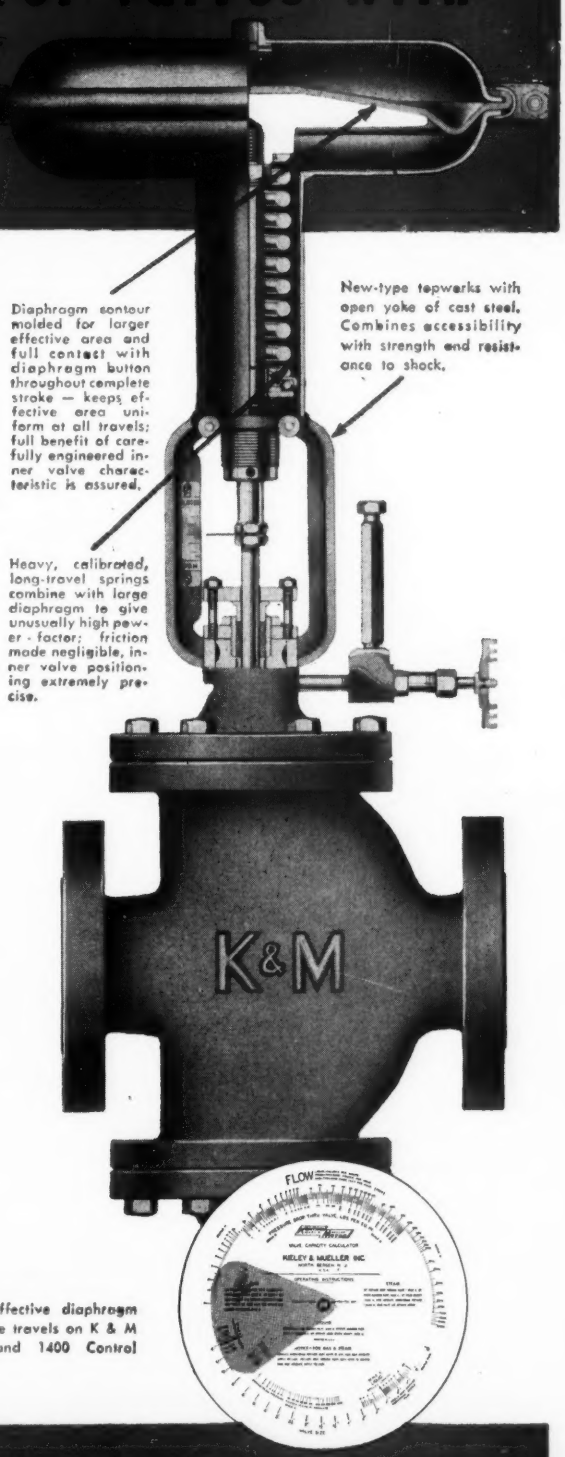
BAILEY METER COMPANY LIMITED, MONTREAL, CANADA

Let Bailey Smoke Density Recorders Watch Your Stacks

K&M The Control Valves with GREATER POWER for GREATER ACCURACY

The Diaphragm Motor of the far-advanced K & M Control Valve is designed for the more exacting needs of modern process industries. An unusually high power-factor is obtained by the carefully-engineered relationship of large effective diaphragm area and heavy, calibrated spring; friction is negligible, inner valve positioning more precise. The diaphragm is specially designed for constant affinity with the button contour; this assures a uniform effective area throughout the complete valve stroke, thus more uniformly accurate control. The unusually large area of the diaphragm in relation to the valve size also helps assure more precise control.

K & M motors are available for direct action or reverse action without change in effective area or stroke.


Diaphragm contour molded for larger effective area and full contact with diaphragm button throughout complete stroke — keeps effective area uniform at all travels; full benefit of carefully engineered inner valve characteristic is assured.
New-type topworks with open yoke of cast steel. Combines accessibility with strength and resistance to shock.
Heavy, calibrated, long-travel springs combine with large diaphragm to give unusually high power-factor; friction made negligible, inner valve positioning extremely precise.
K&M
FLOW
KIELEY & MUELLER INC

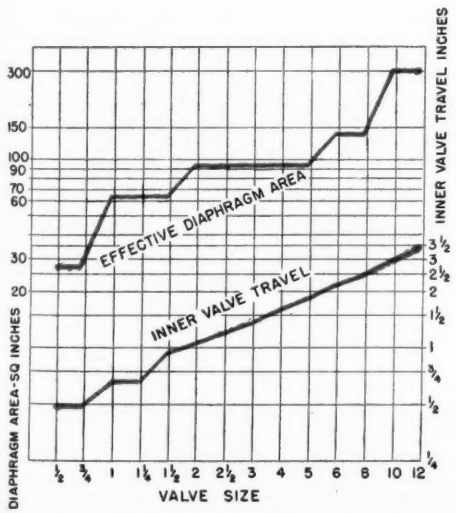


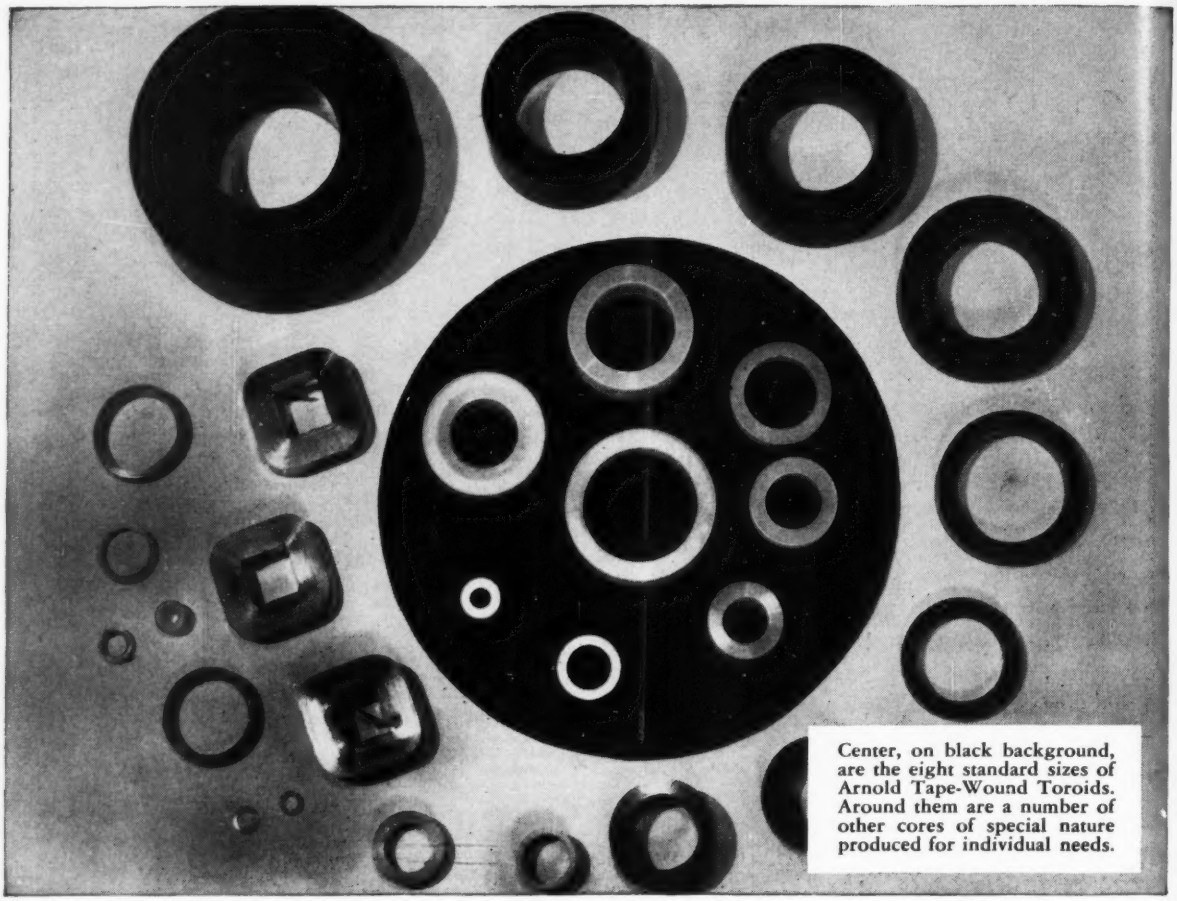
Chart shows effective diaphragm areas and valve travels on K & M Series 1200 and 1400 Control Valves.

KIELEY & MUELLER

Established 1879

2621 —43rd Street North Bergen, N. J.

This extremely accurate circular slide-rule type K & M valve capacity calculator includes corrections scales for steam quality, liquid and gas specific gravity and a flowing temperature scale for gases. Sent without charge or response to request on your business stationery.



Center, on black background, are the eight standard sizes of Arnold Tape-Wound Toroids. Around them are a number of other cores of special nature produced for individual needs.

ARNOLD TAPE-WOUND TOROIDAL CORES

of DELTAMAX 4-79 MO-PERMALLOY SUPERMALLOY*

In addition to the standard toroids described at left, Arnold Tape-Wound Cores are available in special sizes manufactured to meet your requirements—toroidal, rectangular or square. Toroidal cores are supplied in protective cases.

APPLICATIONS

MAGNETIC AMPLIFIERS
PULSE TRANSFORMERS
NON-LINEAR RETARD COILS and TRANSFORMERS
PEAKING STRIPS, and many other specialized applications.

RANGE OF SIZES

Arnold Tape-Wound Toroids are available in eight sizes of standard cores—all furnished encased in molded nylon containers, and ranging in size from ½" to 2½" I.D., ¾" to 3" O.D., and ⅛" to ½" high.

RANGE OF TYPES

These standard core sizes are available in each of the three magnetic materials named, made from either .004", .002" or .001" tape, as required.

**Manufactured under licensing arrangements with Western Electric Company.*

W&D 3182

THE ARNOLD ENGINEERING COMPANY

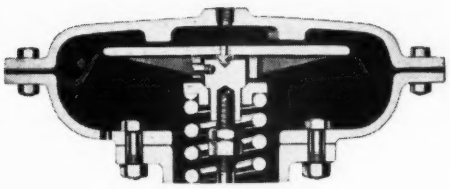
SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

COMPARE

THIS FEATURE

OF THE HONEYWELL SERIES "700" VALVE



Pre-Molded Neoprene Diaphragm, with rolling action. Eliminates wrinkling or buckling . . . responds to slightest change in signal air pressure . . . withstands excessive pressures . . . available with cotton or nylon reinforcement . . . permits use of gas as actuating medium.

Duplex Upper Stem Guide

Packless Bellows Seal

Safety Stem Lubricator

One-Piece Bonnet

Wide Variety of Discs

Reversibility in the Field

* Compare the diaphragm assembly of this valve with that of any other wide band proportional type. Look at it closely . . . study it feature by feature.

Then check the other features of the valve . . . the Duplex Stem Guide, the One-Piece Bonnet, the Packless Bellows Seal, the Safety Stem Lubricator, the wide variety of discs, the easy reversibility in the field from direct to reverse acting, or vice versa.

Your comparison will prove that the Honeywell Series 700 has *all* the features you look for in a fine valve.

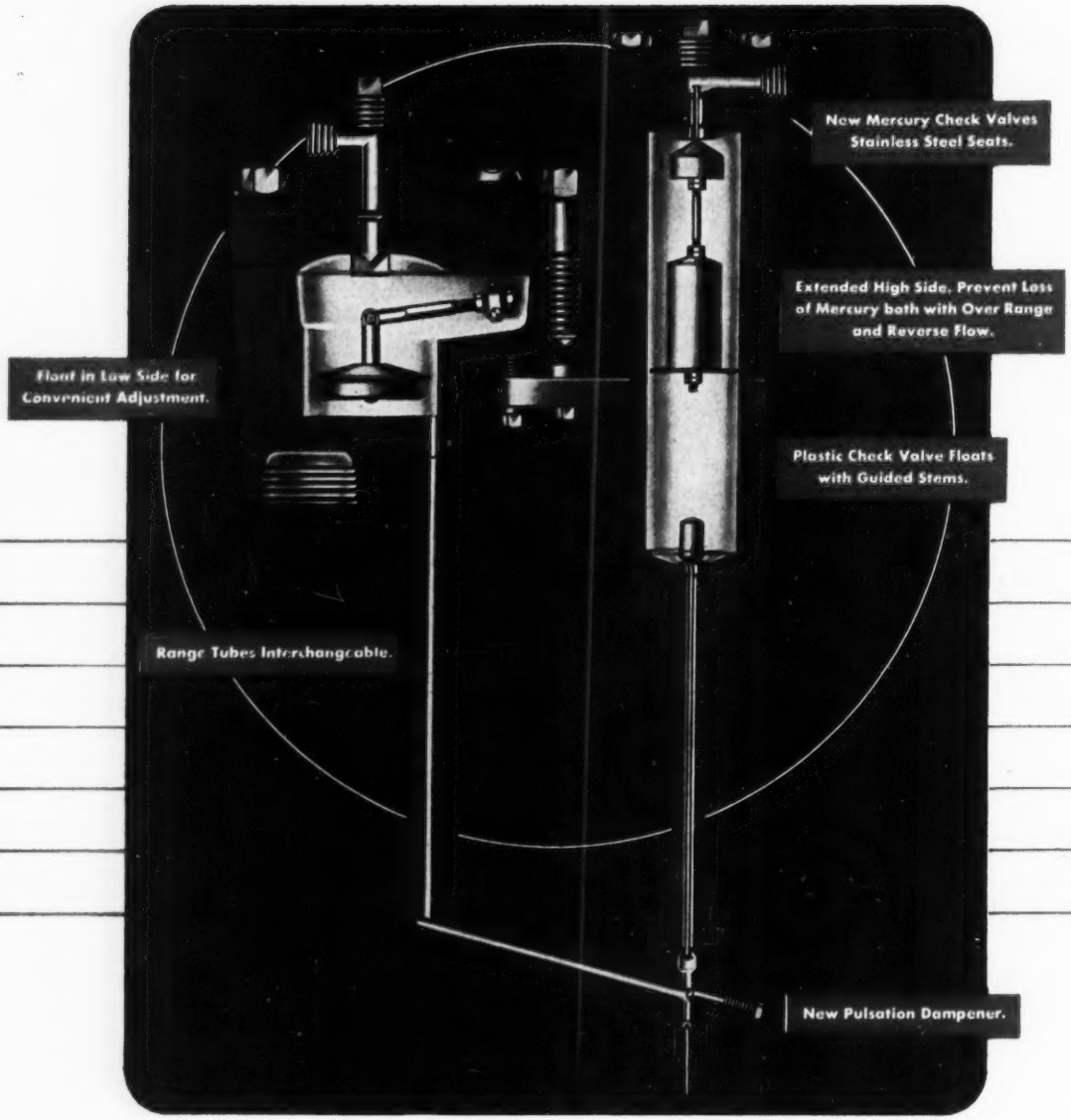
It's available in a wide range of styles and sizes. For detailed information, write for a copy of Bulletin 750 or call in your local Honeywell engineer . . . he is as near as your phone.

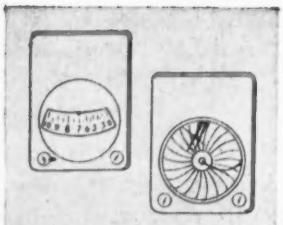
MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 1908 Windrim Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

MINNEAPOLIS **Honeywell**

VALVE PRODUCTS

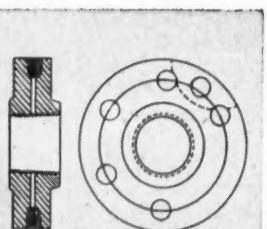
accurate • sensitive a


New Mercury Check Valves Stainless Steel Seats.
Extended High Side. Prevent Loss of Mercury both with Over Range and Reverse Flow.
Float in Low Side for Convenient Adjustment.
Plastic Check Valve Floats with Guided Stems.
Range Tubes Interchangeable.
New Pulsation Dampener.

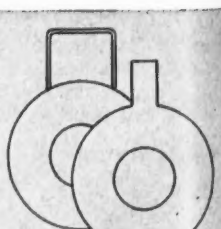


PNEUMATIC TRANSMITTERS AND CONTROLLERS
(Bulletin CT-49)

HIGH PRESSURE IRONCASE DISPLACEMENT METERS
(Bulletin 50-A)



FLANGES
(Bulletin EG-2)



ORIFICES
(Bulletin EG-2)

PILOT
CAPACIT

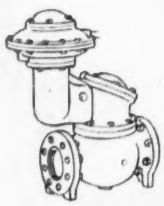
and built for 5000# w.p.

In response to insistent demands from gas and oil production men, the Model A-88 5000# American-Westcott Orifice Meter has been developed for high pressure services.

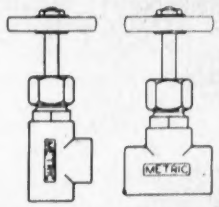
Designed in every way to operate safely and accurately under these pressures, the Model A-88 5000# Orifice Meter provides every feature that has made American-Westcott Orifice Meters outstanding for accuracy, simplicity and low maintenance cost. Its new design incorporates the proven features of the American-Westcott Orifice Meter and the many recent improvements in the A-88 Series to provide an accurate, rugged meter for today's higher operating pressures.

1. **Available in 50" and 100" ranges.**
2. **Low-side body constructed of forged steel of high tensile strength — high-side body made of extra heavy seamless steel.**
3. **Hydrostatically tested to 10,000 psi.**
4. **Adjustments easily made without disturbing working parts.**
5. **All parts can be handled and adjusted by small standard tools.**
6. **Every part accessible for cleaning without removing or loosening any connections that affect accuracy.**
7. **High sides interchangeable without affecting gage line connections.**

These and other American-Westcott features provide simple, accurate, dependable orifice meters that will handle the toughest kinds of measurement problems under the most rugged field conditions, with a minimum of servicing. They maintain to the highest degree the century old American Meter Company tradition of "sustained accuracy at lower cost." Write for descriptive matter.



PILOT LOADED, LARGE CAPACITY CBV REGULATOR
(Bulletin 50)



NEEDLE VALVES, SCREWED AND UNION BONNET
(Specification Sheet)

AMERICAN METER COMPANY
INCORPORATED (ESTABLISHED 1836)

GENERAL OFFICES • 60 EAST 42nd STREET, NEW YORK 17, N. Y.

60 East 42nd Street • New York 17, N. Y. • Albany
Alhambra • Atlanta • Baltimore • Birmingham
Boston • Chicago • Dallas • Denver • Erie
Fort Lauderdale • Houston • Kansas City • Los Angeles
Minneapolis • Odessa • Philadelphia • Pittsburgh
San Francisco • Tulsa.

In Canada—Canadian Meter Co., Ltd., Hamilton, Ontario.

Compressed Air Controls High Vacuum

...AND DPi HAS 10 SIZES OF VALVES TO DO IT

DPi NOW OFFERS pneumatically operated valves in the smaller sizes, as well as the larger sizes previously available.

This means that now, with DPi's complete line of valves ranging in size from 3" to 32", you're assured of instant, sure-seal control, for any size high vacuum system.

In the new smaller-sized pneumatic valves, compressed air at 50 p.s.i. provides a positive seal that can be put into action instantly by electric controls, and will hold indefinitely. The small combined size of valve and operator means easy installation where space is at a premium. You get convenient, automatic operation for your high vacuum system . . . enjoy the advantages of both compressed air and remote electric control.

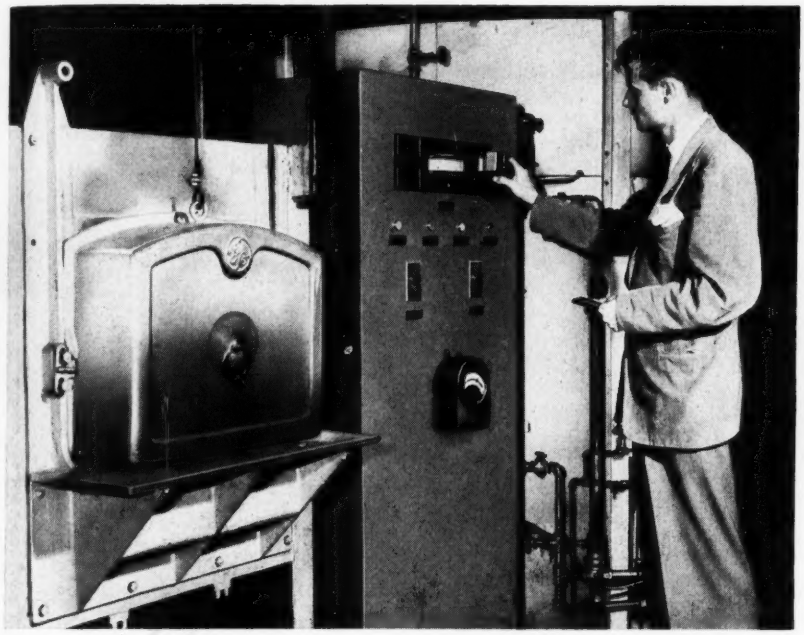
These new valves are another step in DPi's continuing program to make industrial applications of high vacuum as convenient and automatic as possible. As specialists in the design and building of high vacuum installations—whether it be a special valve or a complete system—DPi invites your inquiries. Write to ***Distillation Products Industries,*** Vacuum Equipment Department, 765 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company)

high vacuum research and engineering

DPi

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3400 Eastman Organic Chemicals for science and industry.

PRESENTING . . . THE NEWEST IN PROCESS TEMPERATURE CONTROL



This General Electric Type HP-3 Pyrometer controls a ribbon-resistor box furnace.

PYROMETER EQUIPMENT

With the introduction of this completely new line of Pyrometer Equipment, General Electric offers you accurate indication and temperature control of furnaces, ovens, kilns, and other industrial-heating equipment.

ACCURATE INDICATION. Calibrated accuracy is within ¾ of 1 per cent of full scale. Automatic cold-junction compensation assures that changes in ambient temperature will not appreciably affect accuracy.

CLOSE TEMPERATURE CONTROL. Any change in temperature equivalent to 1/10 of 1 per cent of full scale starts immediate control action. Normal changes in humidity, ambient temperature, and voltage have little or no effect on the exactness of control action.

DEPENDABLE OPERATION. Substantial industrial components and strong construction throughout make G-E pyrometers exceptionally rugged. A 3¼-pound alnico magnet provides high flux density and allows large air gaps; lightweight moving system has high resistance to shock and vibration.

For more details, get in touch with your nearest General Electric representative, or write for Bulletin GEA-5534, "G-E Pyrometer Equipment." Apparatus Dept., General Electric Company, Schenectady, N. Y.

General Electric's pyrometer line consists of flush- or surface-mounted indicators, controllers and protectors. Shown above is Type HP-3 two-position indicating controller. A three-position controller is also available.

GENERAL ELECTRIC

602-198

PRECISION FREQUENCIES

ACCURACY: 1 PART IN 100,000 (OR BETTER) .001%

FOR USE IN SUCH FIELDS AS

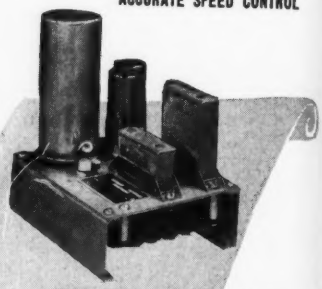
AVIATION
ASTRONOMY
BALLISTICS
HIGH-SPEED PHOTOGRAPHY
VISCOSITY MEASUREMENT
NUCLEAR PHYSICS
TELEMETERING
RADIATION COUNTING
FLUID FLOW
CHEMICAL REACTION
NAVIGATION
SCHOOL LABORATORIES
INDUSTRIAL RESEARCH LABS.
ACCURATE SPEED CONTROL

The controlling unit of these frequency standards is a bi-metallic fork, temperature-compensated and hermetically sealed against humidity and variations in barometric pressure. When combined with related equipment, accurate speed and time controls are afforded by mechanical, electrical, acoustical or optical means.

Instruments of our manufacture are used extensively by industry and government departments on such precision work as bomb sights and fire control.

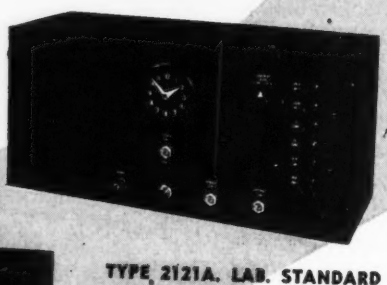
Whatever your frequency problems may be, our engineers are ready to cooperate.

When requesting further details, please specify the Type Numbers on which information is desired.

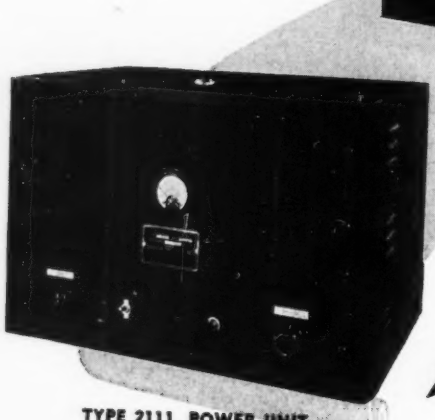


TYPE 2001-2. BASIC UNIT
Frequencies, 200 to 1500 cycles. Dividers and Multipliers available for lower and higher frequencies. Miniaturized and JAN construction. Output, 6 volts.

TYPE 2005. UTILITY UNIT
consists of Type 2001-2 and booster to provide 10 watts at 110 V at 60 cyc. Input, 50-100 cyc.



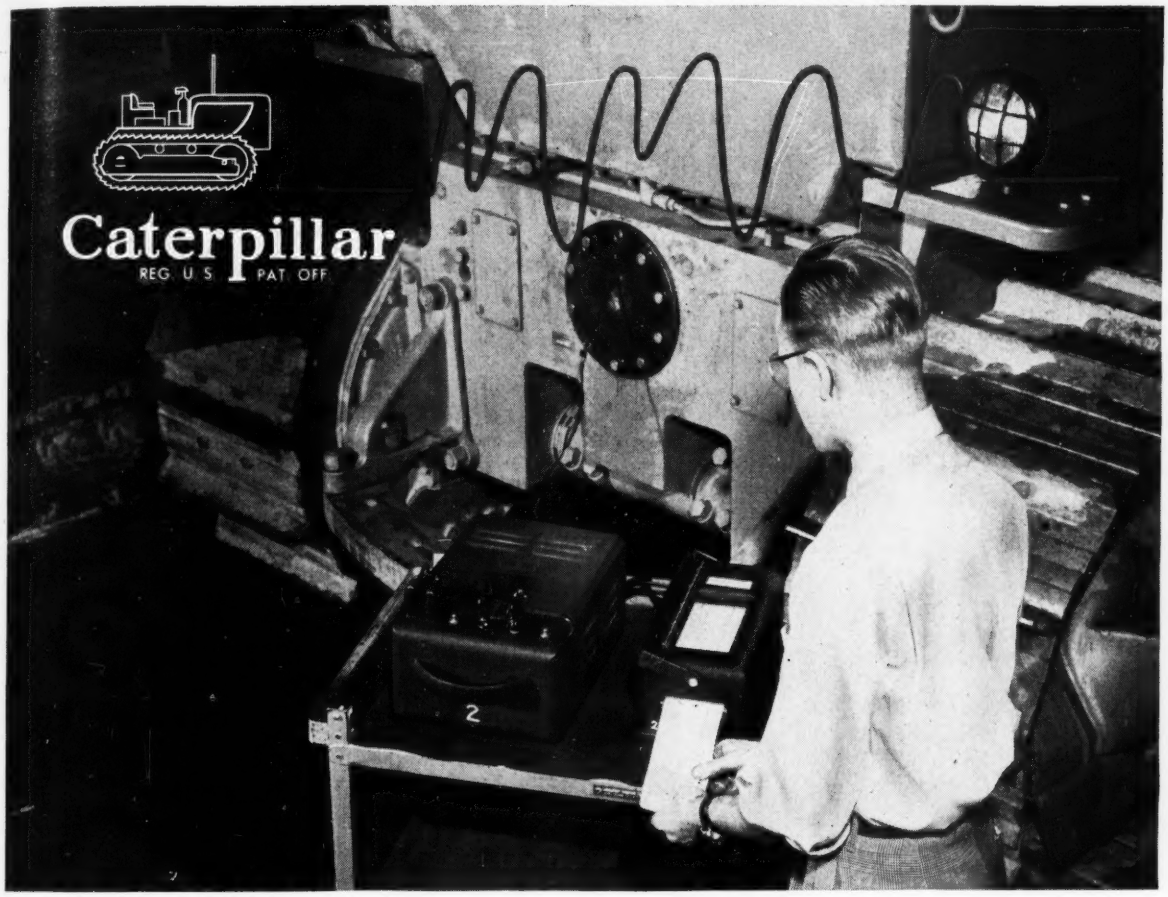
TYPE 2121A. LAB. STANDARD
Outputs, 60 cycle, 0-110 Volts. 120-240 cycle impulses.
Input, 50-400 cycles, 45 W.



TYPE 2111. POWER UNIT
50 W output. 0-110 V at 60 cyc.
Input, 50-100 cyc., 275 W.

American Time Products, Inc.
580 Fifth Avenue *New York 19, N. Y.*

OPERATING UNDER PATENTS OF THE WESTERN ELECTRIC COMPANY



Records dynamic strains of moving engine parts with BRUSH Analyzer

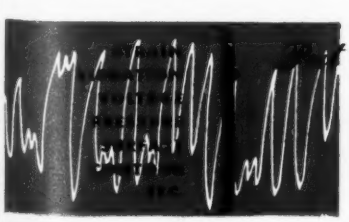
● At Caterpillar Tractor Co., research engineers are constantly seeking to improve performance of engines and components. To do so requires immediate, accurate data of dynamic phenomena. That's where the Brush Strain Analyzer comes in.

In this test on tractor parts, strains are "picked up" with bonded electric strain gages. The signal is amplified in the Brush Universal Amplifier and recorded instantaneously on the Brush Direct Writing Oscillograph.

Other current projects in the "Caterpillar" Research Department are utilizing Brush Strain Analyzers for determining operating stresses in engine parts and components. Set-ups for such tests are laborious and expensive, consequently only the most reliable and precise instruments are used.

With use of a resistance-sensitive pick-up, the Brush Strain Analyzer provides a complete package unit for obtaining permanent records of torque, strain, vibration, pressure and other variables. Write today for further information.

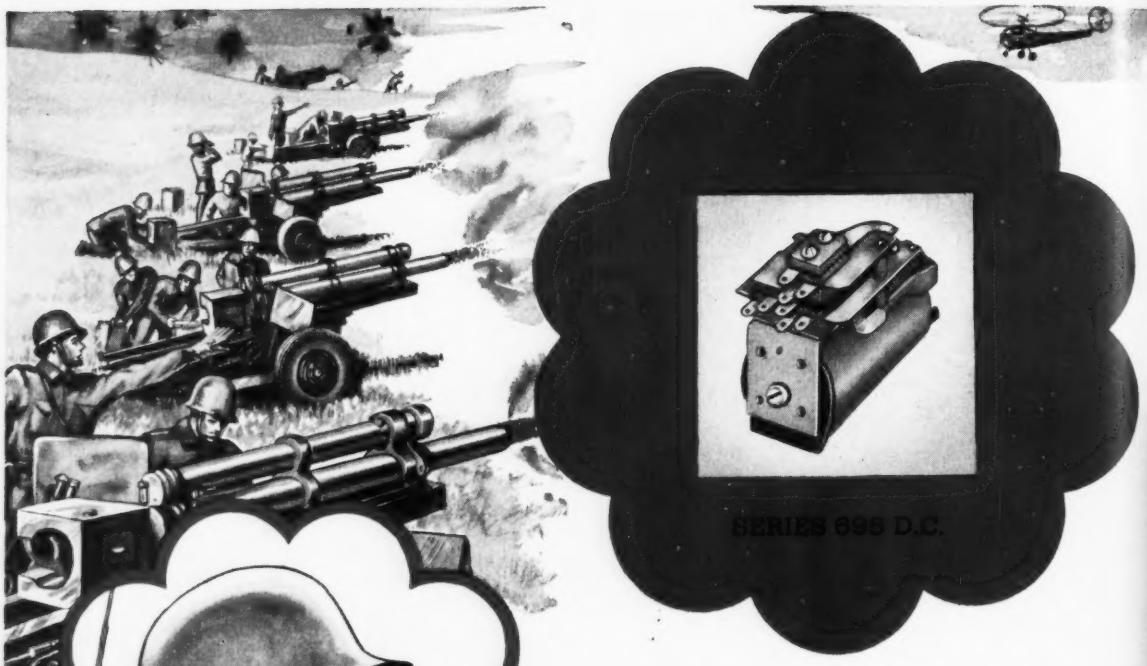
THE *Brush* DEVELOPMENT COMPANY
DEPT. A-2, 3405 PERKINS AVENUE • CLEVELAND 14, OHIO, U. S. A.
Canadian Representatives:
A. C. Wickman (Canada) Limited, P. O. Box 9, Station N, Toronto 14, Ontario
• PIEZOELECTRIC CRYSTALS AND CERAMICS • MAGNETIC RECORDING • ELECTROACOUSTICS • ULTRASONICS • INDUSTRIAL & RESEARCH INSTRUMENTS



it in writing with a

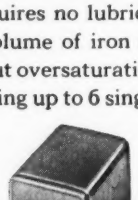
BRUSH RECORDING ANALYZER

STRAIN ANALYZERS • SURFACE ANALYZERS • CONTOUR ANALYZERS • UNIVERSAL ANALYZERS • UNIFORMITY ANALYZERS



ONE OF A LINE

A tiny telephone type—the Guardian Series 695 D.C. Relay has distinguished itself in wartime communications equipment. For inter-plane—intra plane—ground to plane—ship to shore radio—walkie talkie—field telephone equipment—the Guardian Series 695 D.C. is unexcelled. Contrary to conventional design, armature on this relay is formed outward, away from coil, permitting use of a longer coil without increasing overall length of the unit. Armature hinges on a frictionless bearing which requires no lubrication. Proper balance of copper winding and volume of iron on field piece result in maximum flux density without oversaturation of iron. Series 695 D.C. Rélay is capable of carrying up to 6 single pole, single throw contact combinations. Can be hermetically sealed as a standard unit in Lug Header type housing or, to specification, in A. N. Connector, Screw Terminal, or Lug Header type housings.

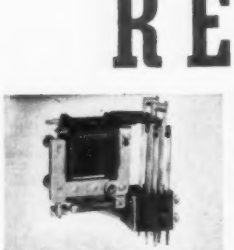


The

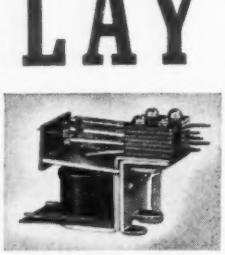
GUARDIAN

SERIES 695 D.C.

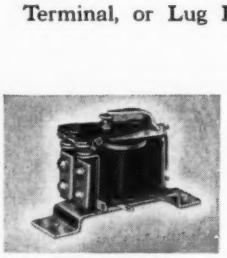
RELAY



Series 30 A.C.

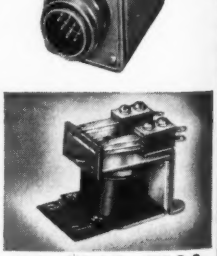


Series 210 A.C.—215 D.C.



Series 220 A.C.

Series 595 D.C.



Series 610 A.C.—615 D.C.

WRITE OR WIRE... FREE CATALOG, SPECIFIC RECOMMENDATIONS, NO OBLIGATION.

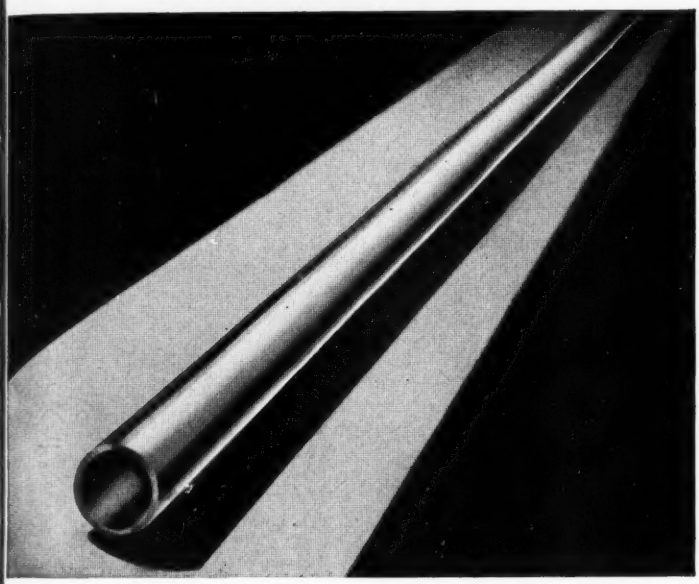
GUARDIAN ELECTRIC

1638-B W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY

To be sold...

at $9,600,000 per ton!

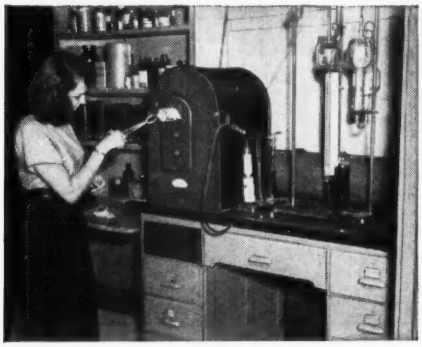


● $9,600,000 a ton isn't hay. Yet it is a reasonable price for 2" O.D. tubing after it has been drawn down to a diameter less than that of human hair.

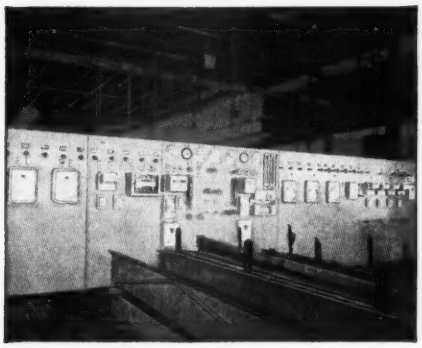
We believe we can supply you with small tubing—normally .010" to .625" O.D.—in more sizes, analyses, and forms (either Seamless or WELDRAWN*) than any other manufacturer. In brighter finishes. To closer tolerances. And with uniformity.

Our service, because of our scope, permits recommendations without bias . . . offers know-how, facilities and equipment only possible because of superior concentration on small tubing—technology in tubing.

You also have a time advantage in dealing with Superior—with distributor warehouse stocks in 55 locations throughout U. S. and Canada. These distributors offer not only availability, but helpful engineering service. Should you stump them—we're ready to jump in at any time to help. Let us send you our Bulletin 31. Superior Tube Company, **1968** Germantown Avenue, Norristown, Pennsylvania.



Routine tests are made to determine the carbon content of both raw material and finished tube. No effort has been spared to produce the highest quality small tubing.



Bright annealing and heat treating furnaces, with instrumentation for control, assure uniform structure, a clean smooth surface and precise temper tolerances.

Final Inspection where each finished length of tubing is inspected for outside and inside finish, size and straightness.

Which Is The Better For Your Product . . .

SEAMLESS . . . ? The finest tubes that can be made. In all O.D.'s from 1⅜" and lower. Excellent for forming, bending, machining, etc. carbon, alloy, stainless, non-ferrous and glass sealing alloys.

Or WELDRAWN* . . . ? Welded and drawn from bright-annealed, cold rolled strip. Economical. Available in stainless, non-ferrous and glass sealing alloys, but not in as wide a range of sizes as seamless.

Superior

THE BIG NAME IN SMALL TUBING

All analyses .010" to ⅝" O.D.
Certain analyses (.035" max. wall) Up to 1⅜" O.D.

*Reg. U. S. Trademark — Superior Tube Company • West Coast: PACIFIC TUBE COMPANY, 5710 Smithway St., Los Angeles 22, Cal. • ANgelus 2-2151

specify Sorensen

AC VOLTAGE REGULATORS

Accuracy, with rugged construction, economical and trouble-free operation, reasonable cost — those are features that you expect, *and get*, when you specify Sorensen regulators!

ALL SORENSEN REGULATORS HAVE THESE ADVANTAGES:

- WIDE INPUT RANGE
- ADJUSTABLE OUTPUT VOLTAGE THAT STAYS SET
- REGULATION ACCURACY OF ± 0.1%
- EXCELLENT WAVEFORM
- FAST RECOVERY TIME
- INSENSITIVITY TO LINE FREQUENCY FLUCTUATIONS.

MODEL NO. 500-S

STANDARD AC SPECIFICATIONS

VA capacity	150 500	250 1000	2000 3000	5000 10000 15000
Harmonic Distortion	3% max.	2% max.	3% max.	3% max.
Regulation accuracy	± 0.1% against line or load			
Input voltage	95-130 VAC; also available for 190-260 VAC single phase 50-60 cycles			
Output voltage	Adjustable between 110-120; 220-240 in 230 VAC models			
Load range	0 to full load			
P.F. range	Down to 0.7 P.F. All models temperature compensated			

NOTE: THREE PHASE AND 400 CYCLE REGULATORS ALSO AVAILABLE. ALL REGULATORS CAN BE HERMETICALLY SEALED.

Write for Complete Literature

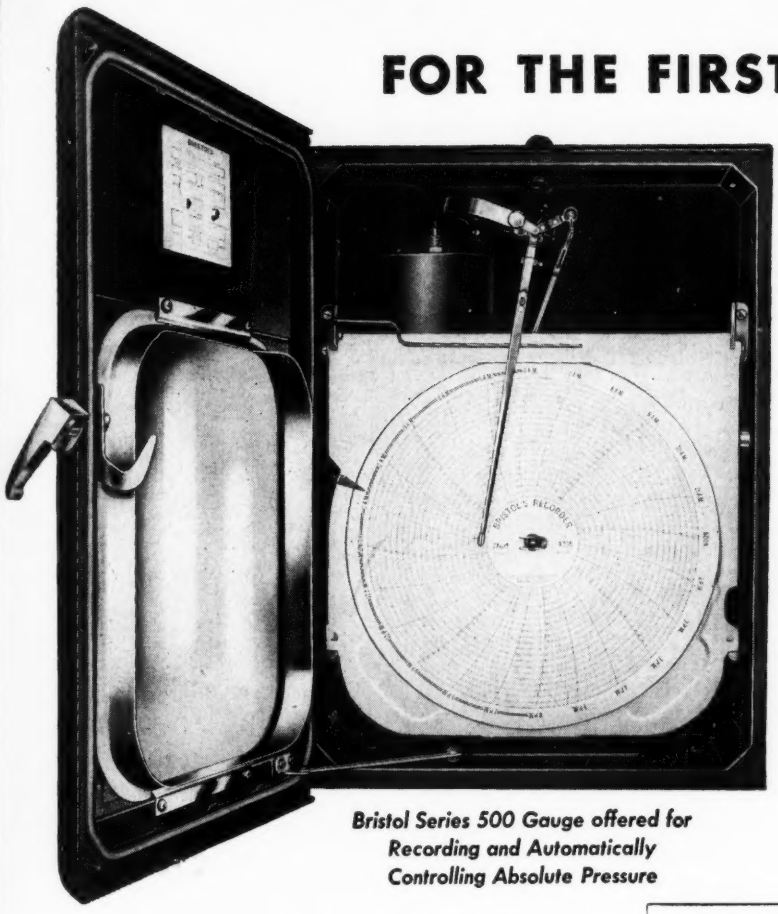
For regulated DC problems investigate Sorensen's line of Voltage Reference Standards, DC Supplys, and NOBATRONS

POWER controlled converted

Sorensen and company, inc.
375 FAIRFIELD AVE. • STAMFORD, CONN.

MANUFACTURERS OF AC LINE REGULATORS, 60 AND 400 CYCLES; REGULATED DC POWER SOURCES; ELECTRONIC INVERTERS; VOLTAGE REFERENCE STANDARDS; CUSTOM BUILT TRANSFORMERS; SATURABLE CORE REACTORS

FOR THE FIRST TIME



Bristol Series 500 Gauge offered for Recording and Automatically Controlling Absolute Pressure

Accurate Mechanical Recording and Controlling of Absolute Pressure

IN RANGES AS LOW AS 0 TO 6 MM!

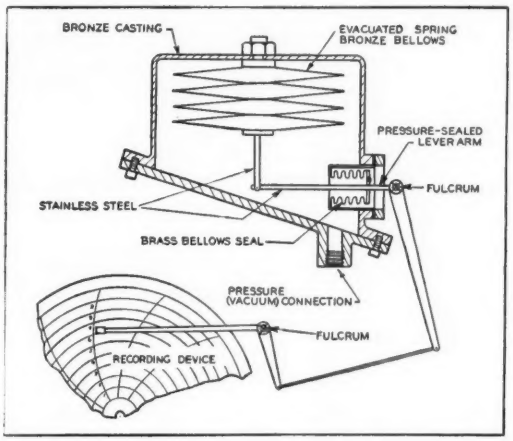
Again, Bristol scores a first!

Our new Low-Range Absolute Pressure Recording Gauge gives a direct reading of pressure above zero absolute, inherently corrected for barometric variations, with far greater accuracy than ever before possible—measuring ranges as low as 0 to 6 mm mercury absolute.

SINGLE BELLOWS—NO COMPENSATION NEEDED

Instead of *two* pressure elements—one for measured pressure, one to compensate for barometric pressure—Bristol uses a single calibrated bellows element, evacuated to practically a perfect vacuum, enclosed in a cast bronze pressure-tight housing. The bellows motion is transmitted outside the housing through an entirely new device—a pressure-sealed lever arm that is frictionless, entirely free from lost motion and turning moments due to changes in differential pressure across it.

Thus—with one measuring element, Bristol's Absolute Pressure Gauge operates in ranges hitherto considered impractical with metallic elements.



WHAT'S YOUR APPLICATION?

This entirely new, highly-accurate, direct-reading mechanical pressure instrument gives valuable information for controlling pressure wherever the operation of equipment depends upon a high and constant vaccum.

Bristol Low-Range Absolute Pressure Gauge is offered for recording, pneumatic or electric controlling, and pneumatic or electric remote transmission. For Bulletin G620, write THE BRISTOL COMPANY, 113 Bristol Road, Waterbury 91, Conn. (The Bristol Co. of Canada, Ltd., Toronto, Ont.; Bristol's Instruments Co., Ltd., Lynch Lane, Weymouth, Dorset, England.)

BRISTOL

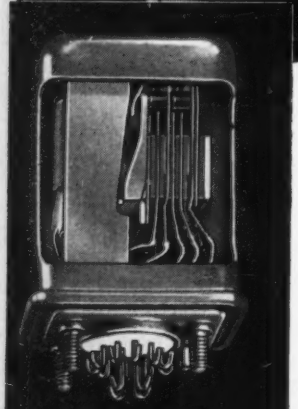
Engineers Process Control for Better Products and Profits

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

THIS IS THE REASON

CLARE SEALED RELAYS

Can't Leak!



Cut-away View
CLARE Type "K"
ermetically Sealed Relay

● Pictured here are ten CLARE Sealed Relays from which every trace of moisture and gas is being removed by a high vacuum pump.

After the first pumping, the enclosures are flushed with dry nitrogen and again pumped down to a few microns pressure. While under this extreme vacuum, enclosures and seals are tested for leaks by means of the mass spectrometer (right). This device can detect a leak so small that it would take 31 years for one cubic centimeter of air to pass through it.

Containers are next filled with dry nitrogen to a pressure of at least one atmosphere. When the evacuating tubes are pinched off, the enclosures are hermetically sealed.

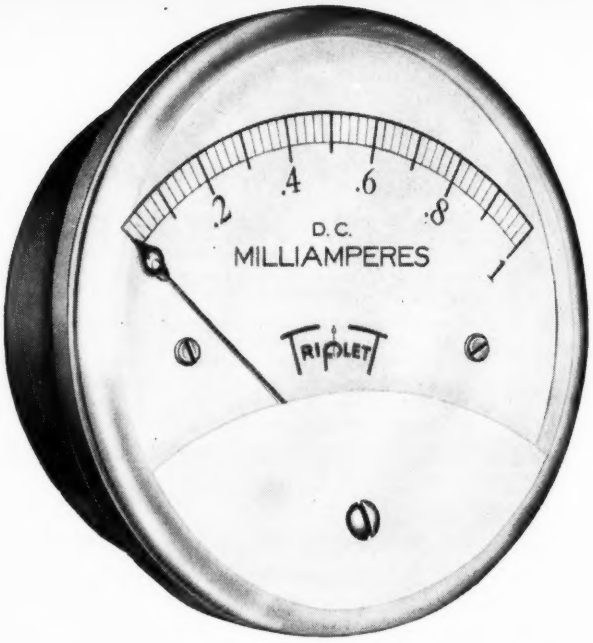
More than forty different series of CLARE hermetically sealed relays . . . immune to every type of climatic or environmental conditions . . . are now available to relay users. Innumerable variations of coil and contact specifications are possible.

If your relay requirement calls for the utmost in relay dependability under difficult operating conditions, get in touch with the CLARE sales engineer nearest you or C. P. CLARE & CO., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Ltd., Toronto 13. Cable address: CLARELAY.

Write for 36-page Clare Bulletin No. 114

CLARE RELAYS...

First in the Industrial Field



Puts new light on "visibility"

—the crystal clear plastic front with clean, rounded edges floods the scale with unobstructed natural light. The dial sets well up into the translucent cover, permitting full natural lighting from the top, sides and bottom. (No bezel or case rim interrupts light from any angle.)

—Another advantage—the full, open dial on this new 3″ instrument gives much longer scale length than on conventional three-inch meters, yet the mounting and panel space is exactly the same.

—Your name or trademark can be shown with colorful emphasis.

Now—with competition getting keener—is a good time to improve your panels. Take a look at Model 321 PL soon.

FOR THE MAN WHO TAKES PRIDE IN HIS WORK

Triplett

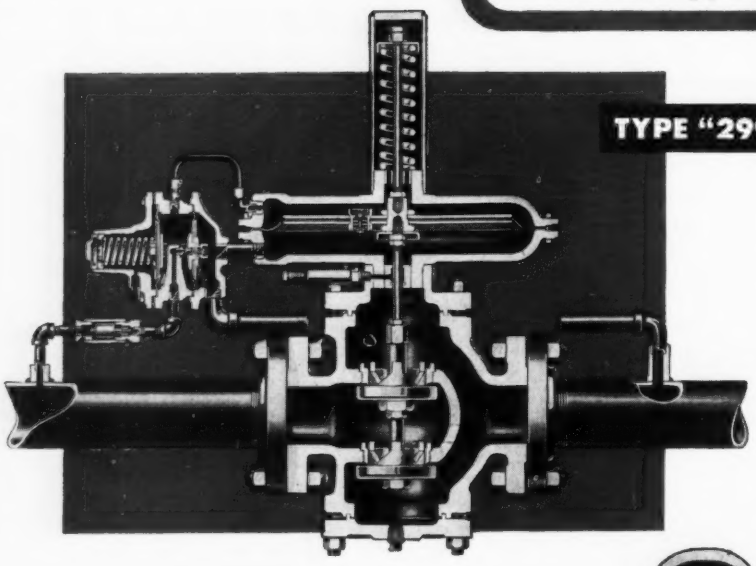
TRIPLETT ELECTRICAL INSTRUMENT COMPANY · BLUFFTON, OHIO, U.S.A.

TRIPLETT ELECTRICAL INSTRUMENT CO., BLUFFTON, OHIO, U.S.A.
In Canada: Triplett Instruments of Canada, Georgetown, Ontario

FISHER® Pressure Reducing Gas Regulators

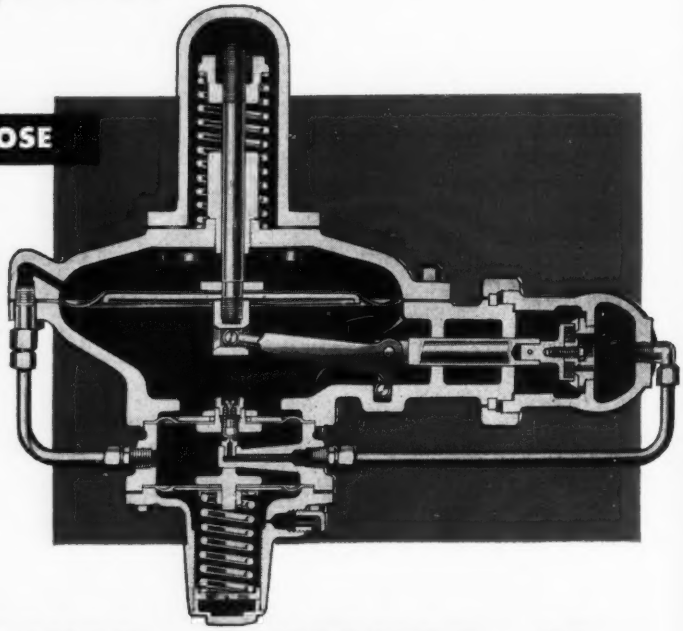
2 Regulators SOLVE HUNDREDS OF GAS CONTROL PROBLEMS

A tremendous range of service conditions can be handled with these two regulators. Similar in principle of operation, they simplify regulator selection problems and give unparalleled performance. Because of their wide range of pressures and capacities, they have solved hundreds of commercial, industrial and pipe line distribution problems.



TYPE "299-61" ULTRA-SENSITIVE

The **TYPE "299"** combines the splendid performance of the Type 99 with valve body assemblies up to 12" flanged connection sizes. High and low pressure units available with double ported construction in either conventional or composition disc inner valves. An **"Ultra-Sensitive"** gas regulator for the big, tough jobs.



TYPE "99" MULTI-PURPOSE

The **TYPE "99"** standard 2" pipe size connections is available for inlet pressures up to 250 psi and outlet pressures down to 3" water column. Proven over and over again on low pressure distribution, intermediate pressure distribution, industrial applications and engine fuel systems. A true **"Multi-Purpose"** gas regulator.

FISHER LEADS THE INDUSTRY IN RESEARCH FOR BETTER GAS PRESSURE CONTROL

FISHER GOVERNOR CO.

MARSHALLTOWN, IOWA

WHAT PRICE PERFECTION!

"PERFECTION" is the most important word in the entire English language to a group of men at John Chatillon & Sons.

These researchers, engineers and planners are constantly working toward the improvement of measuring apparatus that already connotes perfection to every user.

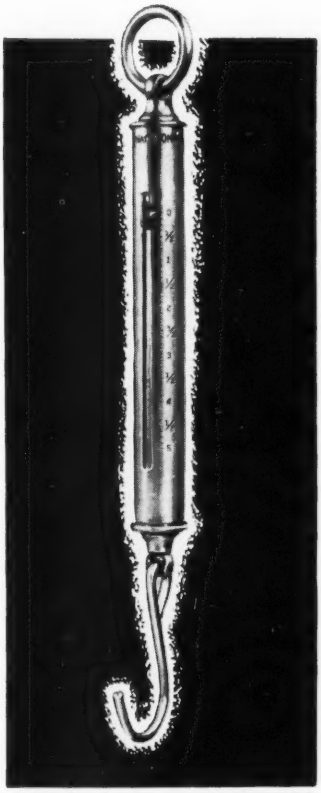
For example: These Force Measuring Devices, which are the finest available, are individually calibrated and guaranteed to be accurate within one graduation mark on the gauge. This exactness is universally accepted, inasmuch as such devices simply are not expected to be more accurate. But — to John Chatillon & Sons, it represents a challenge—and full time research is constantly going on, until "Perfection"—complete and ultimate, is achieved.

"Resting on Laurels" is an invalid phrase at Chatillon.

CHATILLON SPECIAL FORCE MEASURING DEVICES

Only one fine Chatillon Device from Our Complete Line

- For adjusting Spring Tension of D.C. Motor Brush Holder
- For use with Torque Measuring Devices
- For Measuring Force in All Phases of Industrial & Laboratory Work



JOHN CHATILLON & SONS

will design and manufacture Scales and other Measuring Devices to Meet Your Particular Needs.

FILL IN AND MAIL COUPON TODAY

John Chatillon & Sons, 85 Cliff Street, New York 7, N. Y.

Gentlemen: Please send me brochures and price information on

☐ Force Measuring Devices ☐ Traction Dynamometers
☐ Push Pull Gauges ☐ Laboratory Scales

Name..... Company.....

Address..... Position Held.....

JOHN CHATILLON & SONS **85 Cliff Street, Dept. 1 New York 7, N. Y.**

Manufacturers and Designers of Precision Instruments Since 1835

For all your potentiometer needs check this complete L&N line

When you're looking for the right potentiometer to do a specific job, it will pay you to check the *complete* L&N line first. Whether you need the extreme precision of an N.B.S.-certified Wenner, the convenience of a Micromax or Speedomax recorder, or an intermediate instrument, you'll find the characteristics you want in a soundly engineered L&N potentiometer.

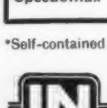
More than a score of models comprise the line. Just glance at the table below. There's a potentiometer for practically any purpose—measurement of low voltages, temperature vs. temperature-difference, calorimetry, pH and other emf cell work . . . self-contained portables for temperature and pyrometer checking . . . and the popular, general-purpose Type K's. Models run from highest to moderate precision. They come in convenient single, double, even triple ranges . . . to suit the job at hand.

Naturally, we can't begin to tell you all you want to know in so short a table. So for complete details, let us send you catalog information. Simply write our nearest office, or 4955 Stenton Ave., Phila. 44, Pa.

MODEL	CAT. NO.	PURPOSE	LIMIT OF ERROR†					RANGE
			better than .01%	.01%	.02%	.03% to .1%	.3% of range	
Wenner (N.B.S.-certified)	7559	thermocouple; other low voltages	x					0 to 0.011111 v; 0 to 0.11111 v
	7558	maintain primary standards	x					0 to 0.19111 v; 0 to 1.9111 v
White (Single)	7620	thermocouple voltages; calorimetry			x			0 to 0.01 v
	7621	thermocouple voltages; calorimetry			x			0 to 0.1 v
White (Double)	7622	temp; temp-difference;			x			0 to 0.01 v
	7623	temp-current; etc.			x			0 to 0.1 v
Type K-1	7551	general		x				0 to 0.161 v; 0 to 1.61 v
Type K-2	7552	general		x				0 to 0.0161 v; 0 to 0.161 v; 0 to 1.61 v
Students'	7651	general				x		0 to 0.016 v; 0 to 1.6 v
Indicator *	7655	pH, emf's				x		0 to 1.110 v
*	7659	corrosion testing					x	triple; 0 to 4.1 v total
Millivolt *	8667	pyrometer check (lab.); temp.				x		0 to 111 mv
Indicator *	8656 B,D,X	pyrometer check (plant); temp.					x	0 to 16 mv; 0 to 70 mv; or as spec.
*	8657	pyrometer check (plant); temp.					x	0 to 16 mv & 16 to 64 mv; or as spec.
*	8662	pyrom. check (lab. & plant); temp.				x		0 to 16.1 mv; 0 to 80.5 mv
*	8658	pyrom. check (lab. & plant); temp.					x	single; direct-reading temp.
Temperature *	8659	pyrom. check (lab. & plant); temp.					x	double; direct-reading temp.
Indicator *	8663-CD	body temps.					x	25 to 125 F; −3.9 to +51.7 C
*	8663-X	temp. check (lab. or plant)					x	single or double, as spec.
Panel Indicator *	8671-76	temp. meas.					x	single or double, as spec.
pH Indicator *	7663-A1	pH; emf cell potentials					x	0 to 13 pH; 0 to 1.100 v
Brooks (Deflection)	7630	ammeter, voltmeter, wattmeter test.				x		0 to 153 mv (used with volt boxes and shunts)
	7640	lamp efficiency test.				x		0 to 1.53 v (used with volt boxes and shunts)
Micromax *		automatic indicating, recording, controlling: voltage, temp., pH, etc.					x	as spec.
Speedomax *							x	as spec.

*Self-contained: battery, standard cell, and galvanometer inside case.

†Under normal operating conditions, except when using lowest part of ranges.



MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

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EDITORIAL

By M. F. BEHAR

"What Is in a Name?"

WHEN Voltaire wrote "I wholly disagree with what you say but I will defend to the death your right to say it," he was writing to Servetus, not to a fuzzy-minded novice. Dr. Klopsteg's career—which began forty years ago with teaching physics at Minnesota—has benefited several pure sciences and industrial technologies.

* * *

One thing Dr. Klopsteg's letter omits to mention is the factual record of how the word instrumentation came to acquire a non-musical meaning, how "instrumentation" (small i) came to mean an orderly group of things and how "Instrumentation" (capital I) came to denote a science—a new progressive human activity composed of several ingredients of which Instrumentology is only one. Perhaps he neither knows nor cares. Others know and care, because these facts are pertinent. Fact Number One—overshadowing all others and determining whether opinions are valid or groundless—is that in 1924 there was undertaken the formulation of a new body of organized knowledge composed of old and new ingredients (i.e. a science)—not, at first, as a new science but modestly as a new branch of science and technology—the branch pertaining to instruments. It was a humble project; the founder was not a well-known scientist but a little-known engineer. About two dozen names were discussed by correspondence and at conferences. The one that stuck was the first one that had been proposed, namely Instrumentation, although it met fierce opposition for about seven years on the ground that it had belonged to music for a century or more. As the formulation progressed, it became evident that a new science was emerging—not only new interrelations and correlations of existing mental constructs which had not previously been codified, not only new generalizations, but new concepts, new principles, even new "laws" in a non-Physics sense.

Fact No. 2 is that all but one of the scientific and technical societies, schools, etc., that were approached ridiculed the project—in some cases fought it—until a year after the foundation in 1928 of The Instruments Publishing Company.

Fact No. 3 is that this private enterprise came to the rescue: the Instruments Publishing Company was the only organization that had the vision to offer to serialize the writings of a little-known engineer, knowing full well that bigwigs of science had brushed aside his formulation as a needless new specialty in a world too full of narrowly-specialized sciences and technologies.

Fact No. 4 is that these serials ran in *Instruments* for six years (1930-35), and totaled half a million words; that the first three "Parts" were issued in book form by The Instruments Publishing Company; and that the title included the word Instrumentation.

Fact No. 5 is difficult to report without excessive enthusiasm. It is that under the name of Instrumentation, a diversified and unified new body of knowledge, written by a number of contributors, has revolutionized not only most industries but several scientific fields. Without Instrumentation and its tangible product (namely instrumentation) there would be no synthetic rubber, no atomic energy, no modernized aviation, no automatization of drudgeries in computation, inspection, etc.

Fact No. 6 is that—as stated in print ten years ago—the science of Instrumentation is "like a fast-growing tree whose roots and branches are fast multiplying. It is like the banyan tree which sends, from some of its branches, downward shoots which take root and develop into accessory trunks so that the tree becomes a grove . . . in the last few years twenty or thirty [other individuals contributing] accessory trunks—each the main trunk now!" These last five words are not an opinion but a fact—the fact that the work

Continued on page 197

Instrumentology *and* Instrumentation

By PAUL E. KLOPSTEG, Director of Research, Northwestern University

PHYSICAL measurement in all the experimental sciences and engineering, and the instruments and controls derived from the variation of some physical quantity with changes occurring in the object of investigation, have been becoming increasingly important during the past several decades. It has been implicitly and explicitly recognized through the years that progress in science and engineering is profoundly dependent upon them. A theory or an hypothesis becomes a valid and acceptable addition to science to the extent to which it survives experiment, and experiment is largely measurement. Broadly, we are here considering the whole field of instruments and apparatus that constitutes so major a part of the scientist's and engineer's working equipment.

It is perhaps an elementary but important observation that there are two large and important categories of instruments and controls—those that evolve or are used in research and development; and those employed largely in the routines of industry, in testing and control laboratories and in the manual and automatic control of plant processes.

In the research laboratories of universities and the development laboratories of industry, as well as in many government laboratories, a large part of the research worker's time and effort is applied to the instrumental means and techniques to be employed. Numerous new devices and methods have had their inception in such work. In an earlier discussion, I proposed the designation* "instrumentology" for this kind of development, to differentiate it from another aspect—the engineering one—which through the years has become known as "instrumentation." Between the two there is obviously a marked difference.

The difference is well typified by the difference between the papers published in such journals as *Review of Scientific Instruments* and *Journal of Scientific Instruments* on the one hand, and *Instruments* and *Instrument Practice* on the other. The term "instrumentation" rather clearly denotes the engineering and technical aspects of applying well-developed, commercially obtainable instruments and controls to plant operations, and of improving the constructions and functions of such devices. It is used also to denote collectively the instrumental equipment designed for or employed in any project using such means. Instrumentation follows instrumentology—sometimes by a great span of time—on the long road from the laboratory, through development and production engineering to the plant. Unfortunately, "instrumentation" is being used to denote both the aforementioned categories.

Notwithstanding the remark made by a past president of the Instrument Society of America, to the effect that although it is unfortunate that the wrong term has been applied to the science, it is now too late to rectify the error, I must express the view with some emphasis that if an error is recognized it should be corrected, however tardily.

It is clearly erroneous to refer to the science of instruments, particularly in the laboratory stage, and in its application to basic research in the laboratory as "instrumentation." Unless there is a more fully appropriate designation—and I am aware of none—I suggest "instrumentology" as desirably descriptive, and as properly differentiating its field from that of instrumentation.

Because continuation of "instrumentation" to cover both the categories mentioned propagates ambiguity, it seems most desirable that the terms "instrumentology" and "instrumentation" be employed within their proper connotations.

Science 101: 1, 1945

Recording Motion *of a* Watch Balance Wheel *by* Watch-case Reaction

By EDWARD C. LLOYD, Marine Engineer, Bureau of Ships, Navy Dep't, Washington, D. C.*

VARIOUS instruments are available commercially for timing watches by recording the beats of the balance wheel. These instruments are usually of a type that employ a microphone and amplifier arranged to pick up and amplify the sound of the escapement, the amplified signal being utilized to actuate a device that prints a dot on a moving paper tape for each beat of the balance wheel. A record is thus obtained showing the time intervals between successive beats. Such records have been found useful in locating sources of trouble in watches to be repaired, and in determining whether a watch is in proper adjustment, particularly with respect to positional errors in rate.

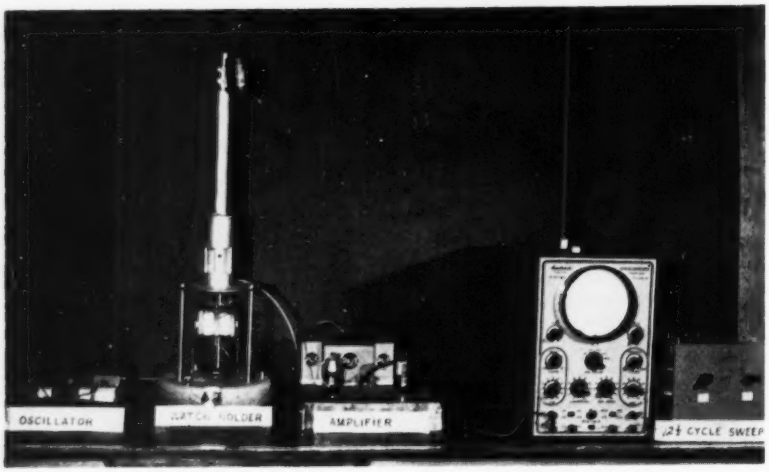

Fig. 1. Equipment for obtaining curves of balance-wheel displacement vs. time on oscilloscope.

Additional useful information might be obtained, however, by means of an instrument that provides a record of the actual motion of the balance wheel throughout its travel; i.e., a curve of balance wheel angular displacement, velocity, or acceleration, as a function of time. Such curves would not only permit a determination of the watch rate but would show variations in amplitude of the balance wheel oscillations and, in principle at least, would show the location and nature of the impulses received from the escapement. A determination of deviations of the displacement, velocity, or acceleration curves from a true sine curve might be of value in studying the characteristics of watches having different types of escapements, different types of hairsprings, etc., and in determining the condition of watches. It may be noted that for best timekeeping qualities the balance wheel motion must approach simple angular harmonic motion as closely as possible, since this is the only type of oscillatory motion whose period is independent of the amplitude and in which a properly applied impulse will not affect the period.[1]

The instrument here described provides a record of balance-wheel motion by recording the motion of the *watch case* of a watch suspended so as to move freely about an axis parallel to the axis of rotation of the balance wheel. Except for a small effect due to the intermittent motion of the escapement, the case of a watch so suspended would evidently move in precisely the same manner as the balance wheel, but in opposite phase, and with an amplitude approximately equal to that of the balance wheel multiplied by λ, the ratio of the moment of inertia of the balance wheel to the moment of inertia of the entire watch and its suspension.

For watches for which λ has a value of the order of 10^{-4} it would be expected that the amplitude of oscillation of a suspended watch would be of the order of 0.01 degree. To verify that a usable signal could be obtained by this method an optical system was devised for recording the watch case motion. A watch was placed in a horizontal position on a pan suspended by a single fine wire, and a record of the motion of the watch and pan obtained by means of a light beam reflected onto a moving photographic film from a mirror attached to the pan. Records so obtained for two wrist watches indicated a motion having a double amplitude of 0.02 and 0.03 deg., and for a large pocket watch of 0.12 deg. The pan and supporting wire used were held in the watch holder shown in Fig. 1, the wire being inside the vertical pipe and secured to an adjustable fitting at the top. The mirror occupied a position inside the lower enlarged section of pipe opposite the rectangular opening shown. Although this equipment gave a fair indication of the amplitude of motion, it was found to be not sufficiently sensitive to provide a record of the motion through the entire cycle, of the accuracy desired. Difficulty was encountered in initial adjustment

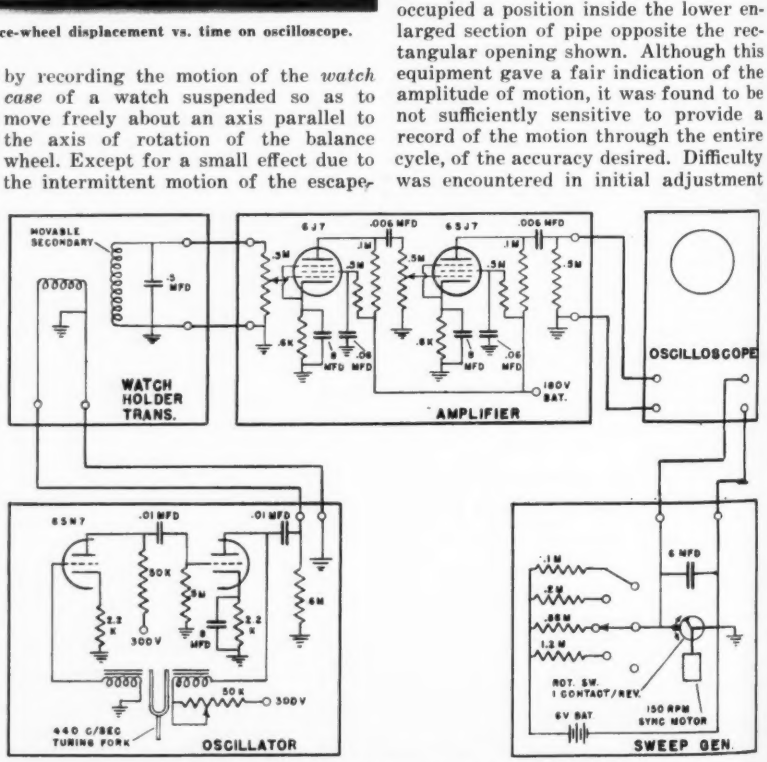

Fig. 2. Wiring diagram for equipment of Fig. 1.

*This article is not related to the author's work for the Navy Department.

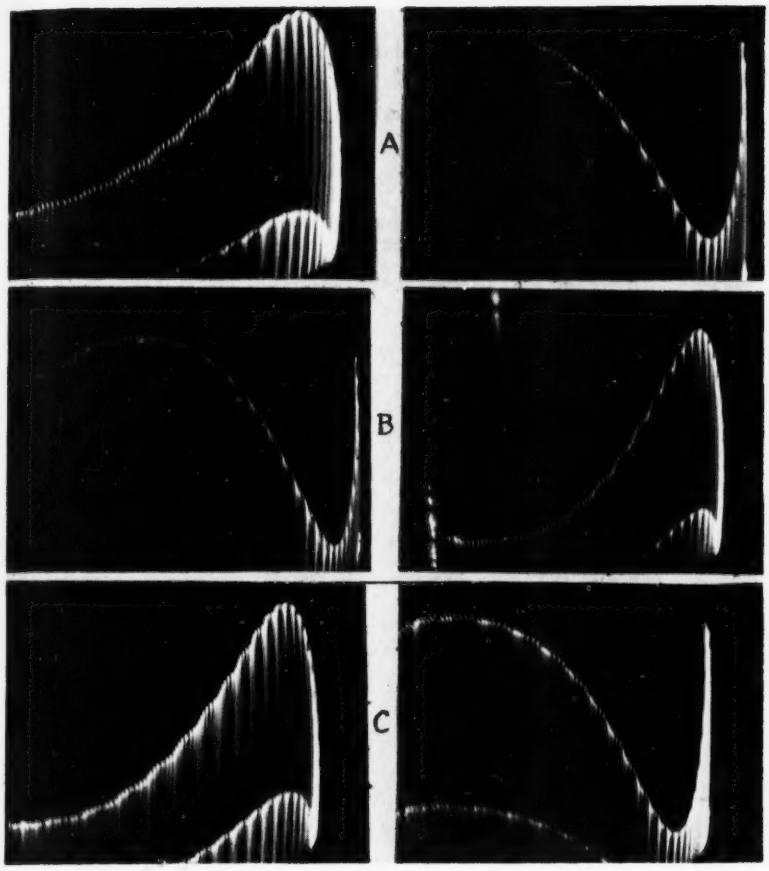

Fig. 3 Photographs of oscilloscope screen for three watches, taken with ⅔ second exposures. Each photograph shows one complete balance wheel cycle. Ripple along curves is due to 60 cycle component.

of the position of the pan and mirror, and in damping oscillations of the suspension system at its natural frequency.

The watch holder was modified to provide an electrical signal derived from the watch motion that could be amplified and displayed on an oscilloscope screen. This was accomplished by the use of an air-core transformer having a movable secondary winding attached to and moving with the watch pan. The primary winding, shown in place in Fig. 1, was placed on a horizontal brass tube; and openings in the coil and tube permitted the pan suspension system to pass through the coil at its center. The secondary winding, consisting of a small ring-shaped coil, was made a part of the suspension system within the primary winding and was oriented in a vertical plane. In use, the watch pan is initially adjusted so that the plane of the secondary coil is parallel to the axis of the primary coil, thus giving a minimum output signal. The principal secondary output voltage is thus proportional to the angle between the axis of the primary winding and the plane of the secondary winding, and hence proportional to the angular displacement of the watch.

The complete equipment is shown in Fig. 1; and Fig. 2 shows wiring connections. A tuning fork oscillator supplies current at 30 volts, 440 cps., to the primary winding of the air-core transformer. The 440-cps. output from the transformer secondary, proportional in voltage to the angular displacement of the watch, is amplified by a factor of about 5000 and fed to the vertical input of the oscilloscope. A 2.5-cps. saw-tooth wave generator, timed by a 150-rpm. synchronous clock motor connected to the 60-cps. power line, supplies the horizontal sweep frequency. Provision is made in the sweep frequency generator for adjusting the phase angle of the output with respect to the phase of the watch balance wheel, and for adjusting the ratio of output voltage to battery input voltage. A 2.5-cps. sweep frequency was chosen since the majority of watches are designed for 18,000 beats per hour, or 2.5 cps., of the balance wheel.

Records made with this equipment for three watches are shown in Fig. 3. The horizontal sweep of the oscilloscope was not linear, due to the characteristic of the oscilloscope horizontal amplifier at the low sweep frequency of 2.5 cps. The resulting distortion of the curves is apparent, particularly near the end of the sweep. Commercially available oscilloscopes designed for use with a sweep frequency of 2.5 cps. or lower would, of course, provide a linear trace. A low-amplitude 60-cps. voltage is superimposed on the signal and provides markers along the trace that permit the curves to be plotted to a linear scale. Such a plot is shown in Fig. 4 for each of the pairs of curves of Fig. 3, together with a true sine curve for comparison. Owing to the curves on the oscilloscope screen being unduly crowded together over the last part of the trace, only the first half-cycle of each trace was used in plotting the curves of Fig. 4. Analysis of the curves of Fig. 4 shows a second harmonic content, at least some of which is attributable to non-linearity of the voltage amplifier used. Use of a push-pull type amplifier would eliminate this source of error in the curves.

In order that motion of the suspended watch exactly follow the motion of the balance wheel, it is evidently necessary that the suspension system have zero natural frequency of oscillation as a torsional pendulum, i.e., that the supporting wire be entirely inelastic in torsion. The use of an inelastic support is inconvenient since the movable coil then has no natural zero position; in practice a suspension system having a natural frequency remote from the balance-wheel frequency will permit the watch motion to follow the balance-

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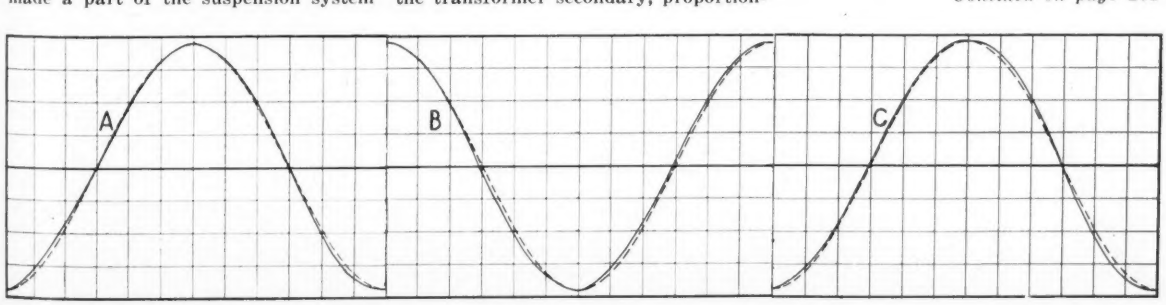

Fig. 4. Solid lines are curves of Fig. 3 plotted to a linear time base. Dashed lines are true sine curves having the same amplitude and frequency.

Construction *and* Calibration *of a* Laboratory Engine Pressure Indicator*

By GREGORY L. LASERSON, Columbia University, New York City.**

THE indicator described below is based on the design of Taylor and Draper,[7] modified to simplify its construction. It was thus possible to construct an accurate pressure indicator at low cost and without a great deal of skilled labor. A few simple calibration tests were sufficient to define the range of maximum errors. It was found that the instrument was accurate to within plus or minus 1 psi. or 1 percent, whichever is larger. This appears adequate for many indicator applications.

This indicator is of the balanced diaphragm type, and was chosen because of its inherent accuracy and simplicity. Since it does not depend upon the elastic deformation of some member for its pressure indication, it is not influenced by the temperature dependence of the modulus of elasticity. Creep or other causes of permanent set are also of no consequence. The recording equipment required for such an instrument consists simply of a Farnboro type drum. Thus oscilloscopes or complex optical recording devices are eliminated, and instrument costs are kept at a minimum. For a detailed comparative analysis of various types of high speed engine indicators reference is made to the bibliography.

The construction of the diaphragm holder is shown in Fig. 1 which is largely self-explanatory. "Teflon" polytetrafluoroethylene was found satisfactory for electrical insulation since it was not affected by the high temperatures encountered. No difficulties were experienced in machining small washers from this material. The spring contact to the center electrode is required to take up thermal expansion in the holder. The two grids which limit the motion of the diaphragm are pierced by twenty holes, distributed in a random pattern and interconnected by concentric grooves. Maximum motion of the diaphragm is limited to about 0.005 in.

The diaphragm itself is of utmost importance for proper operation of the indicator. It was at first considered that corrosion resistance was an important aspect of the diaphragm. Nichrome V was therefore chosen, and diaphragms cut out of 0.003-in. ribbon, such as is used for electrical resistance elements in heater coils. This material was too soft, however, and was badly dimpled, in a pattern corresponding to the grid holes, after a short operating time.[1] Feeler gage stock was then substituted for the Nichrome V. This can be obtained in thickness down to 0.0015 in. and diaphragms may be cut from it with scissors. This material proved highly satisfactory; no dimpling occurred even in a 0.0015-in. diaphragm. During long runs at high loads, these thin diaphragms were blued due to overheating; 0.003-in. stock was therefore used for the majority of tests. Corrosion did not seem to be appreciable even when operating with rather lean mixtures.

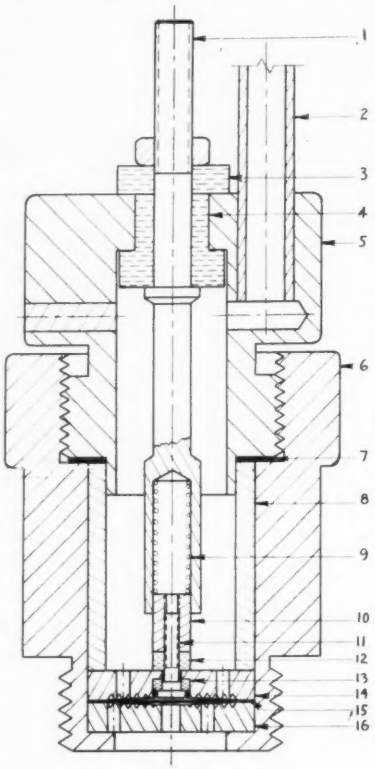

Fig. 1. Diaphragm Holder.

1	Center Electrode
2	Pressure Supply Line
3, 4, 12	Teflon Washers
5	Stainless Steel Cap
6	Stainless Steel Body
7	Asbestos Gasket
8	Spacer Ring
9	Music Wire Spring
10	Contact Nut
11	Contact
13	Soapstone Washer
14, 16	Diaphragm Support Plates
15	Diaphragm

The electronic relay circuit which provides the recording spark is shown in Fig. 2. It comprises two circuits: one operates whenever the diaphragm makes contact; the other when it breaks contact. The desired circuit is chosen by the triple-pole double-throw switch S. In this manner the rising pressure curve is plotted independently of the falling pressure curve, so that only one point is plotted during each cycle. This prevents missing of the recorder spark near the peak of the pressure curve where points of the same pressure occur within a few degrees of crank angle. The thyratron relay has the function of reducing the current required to flow through the diaphragm. Since the latter only controls the grid, arcing and consequent pitting or welding are eliminated. The plate current of the thyratron then flows through the primary of an induction coil (Ford Model T) the secondary of which provides the recording spark voltage. For the details of operation of the circuit the reader is referred to Taylor and Draper.[7]

The recording drum is a 2-inch diameter hollow aluminum cylinder geared to the crankshaft and running at half its speed. The drum is electrically grounded. A sharp pointer may be traversed parallel to the axis of the drum by means of a feed screw. This pointer is connected to the high-voltage side of the spark coil. A manual feed was provided for the pointer rather than a direct pressure-actuated feed. This increases the time required to plot a complete indicator card and permits plotting of discrete pressures only. However, the instrument is thus simplified considerably and, furthermore, the pressure scale may be changed arbitrarily, thus increasing the flexibility of operation.

The circumferential position at which the spark from the pointer hits the drum indicates the crank angle at which the diaphragm makes or breaks contact. The cylinder pressure then equals the balancing pressure. To record this a paper is wrapped around the drum and punctured by the spark. The choice of paper seems to be rather important. Many spark recorders suffer from "spark spraying"; the spark does not take the shortest path from the pointer to the drum. This is ascribed to the fact that the recorder paper may be the controlling resistance in the path and that this resistance may vary over the surface of the paper. If the paper is electrically conducting, the air gap is the controlling resistance and the spark does take the shortest path thus eliminating the "spraying" effect. The paper used to separate photographic plates in packages was found to be highly satisfactory. The high carbon content of the black pigment apparently makes it sufficiently conducting. With very strong sparks tiny holes are punched through the paper. If the sparks are weaker, only surface burn marks are produced which are, however,

*Based on Chapter V of a dissertation submitted by the author in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Mechanical Engineering at Columbia University.

**At present with E. I. Du Pont de Nemours & Co., Wilmington, Del.

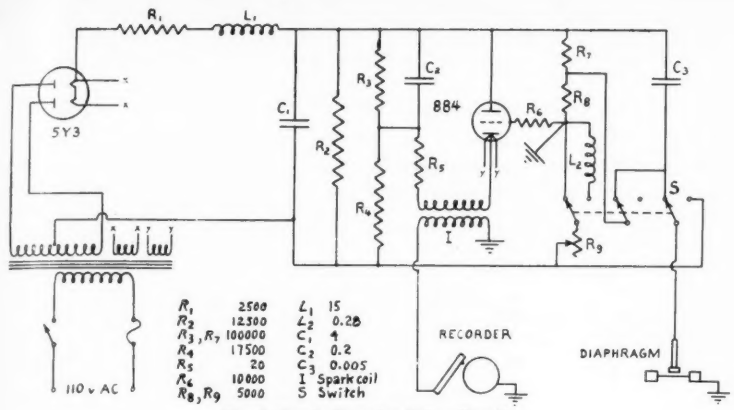

Fig. 2. Spark Recorder Relay Circuit.

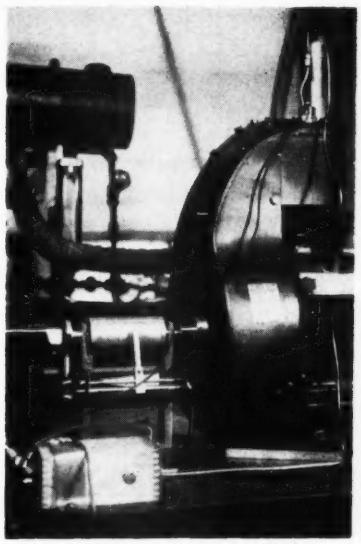

Fig. 3. Engine Indicator Installation.

sufficient to obtain a good indicator card. Since the position of the pointer is not directly dependent upon the balancing pressure, the paper record cannot be used as an indicator card directly. The positions of the holes or burn marks corresponding to the discrete pressure steps at which the balancing pressure had been set are located on the record and are replotted to the desired scale.

Before reliance can be placed in an instrument of this type, the various sources of error must be determined and their contributions to the total error ascertained. There are basically three types of error present:

(1) Difference between the cylinder pressure and the balancing pressure at the time the diaphragm makes or breaks contact.

(2) Difference between the balancing pressure and the pressure indicated by the pressure gages.

(3) Time lag of the instrument.

The cylinder pressure and the balancing pressure necessarily differ by the pressure required to bend the diaphragm and press it against the contact point, or away from it. This is minimized by using the thinnest possible diaphragm. This pressure differential was measured by admitting high-pressure nitrogen to both sides of the diaphragm. By means of bleeder valves the pressure on either side was then reduced until a spark was caused by the motion of the diaphragm. A differential manometer was used to measure the required pressure difference. In this manner the pressure difference was determined for a range of absolute pressures from 0 to 250 psig. It was found that about 1.2 psi. was required to deflect a 0.003-in. diaphragm. Since this pressure was constant within plus or minus 0.2 psi., a correction may be made in the indicator measurements resulting in a probable error of 0.2 psi. due to this cause.

A difference between the balancing pressure and the pressure indicated by the gages is caused by either a pressure drop in the lines connecting the diaphragm to the gages, or by errors in the gages themselves. Since flow rates in the balancing pressure lines can be kept negligibly small, no appreciable pressure drop is caused. Careful checking of the Bourdon gages used, by means of a dead-weight tester, will eliminate any errors due to this source. The gages employed in the present experiments showed no deviations from their dial calibrations.

Time lag of the instrument may be caused by the time required to fill the cavity between the supporting grid and the diaphragm, by the inertia of the diaphragm, and by the time constant of the relay circuit. The effect of these three factors was determined as follows. An indicator card was taken

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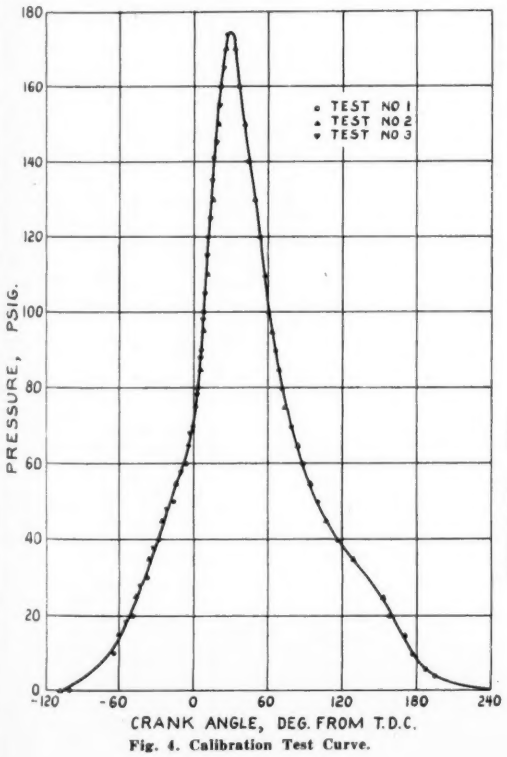

Fig. 4. Calibration Test Curve.

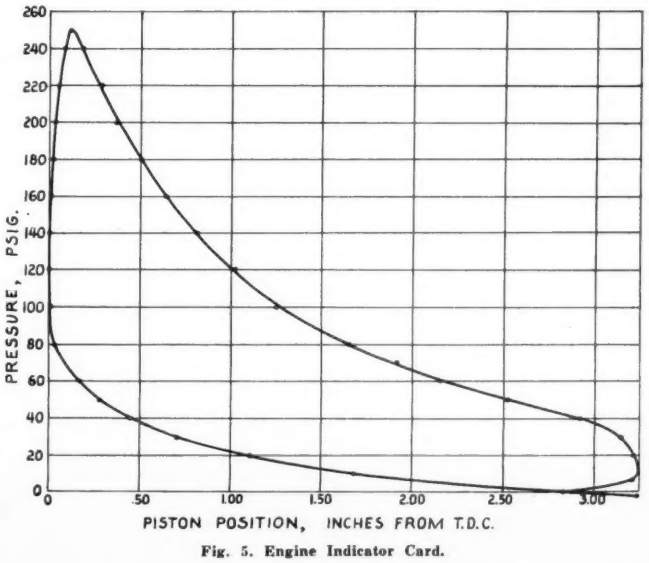

Fig. 5. Engine Indicator Card.

Instrumentation *of an* Ammonia Plant

By PORTER HART and R. C. KING, Texas Division, The Dow Chemical Co.

Introduction

THIS paper does not attempt to describe in detail the process of ammonia manufacture, but rather to bring out some of the applications of process control instruments in the plant. Essentially, the process consists of passing three parts of hydrogen and one part of nitrogen over an iron catalyst at high pressure and moderately high temperature. The ammonia formed is condensed and the unreacted gas recirculated.

The synthetic ammonia capacity of the United States is about 5,000 tons per day. The nitrogen for this production is drawn from the air while 55 percent of the hydrogen is made by the water gas process using coke, 40 percent is made from natural gas and only 5 percent is by-product hydrogen from electrolytic cells. The Dow Chemical Co. uses electrolytic hydrogen in its plant at Freeport, Texas. However, a brief description of the process for manufacturing hydrogen from natural gas may be in order because it is such a plentiful raw material in this area.

Hydrogen Processed from Natural Gas

To make one ton of ammonia, about 22,000 cubic feet of natural gas are required, excluding that needed for power generation. The natural gas and steam are passed over a nickel catalyst at 725C., then air is added for nitrogen, the oxygen being burned by part of the hydrogen. More steam is added and the mixture passed over an iron oxide catalyst to convert the CO to CO_2 while making more hydrogen. This mixture of gases is scrubbed with water at 225 psi. to remove most of the CO_2, compressed to 1800 psi. and scrubbed with ammoniacal copper ammonium formate solution to remove CO and O_2, and finally with dilute caustic to catch final traces of CO_2. The resulting gas contains only 10 to 20 ppm. impurities, mostly as CO.

Hydrogen Collection and Storage (Fig. 1)

The hydrogen from the electrolytic cells is collected in a header system and the pressure raised by blowers, scrubbed, and delivered to the gas holder. The instrumentation of this phase of the operation consists mainly of safety devices. Since any mixture of hydrogen and air between the limits of 40 to 74 percent hydrogen is an explosive mixture, extreme caution must be observed to prevent air from entering the hydrogen lines. The blower suction is maintained at a slight positive pressure by a 0 to 5 inches of water differential type meter used as a pressure controller operating a by-pass valve between the discharge and the suction headers. A gas analyzer records the hydrogen content of the discharge gas.

Alarms are arranged to shut down this system completely and vent the hydrogen to atmosphere in case the suction header pressure goes too high or too low for safe operation, or the hydrogen analysis drops to 98 percent. An interlock with the blower motor will actuate the vent in case the motor stops.

When the hydrogen is received at the gas holder in the Ammonia Plant, its analysis is again checked. The recording analyzer will actuate an alarm if the analysis is below 98 percent. The level in the gas holder is transmitted to the control room by a cable drum mounted on a pneumatic transmitter. The gas holder pressure transmitter records on the same receiver as this level. An auxiliary mercury pressure switch will shut down the ammonia process completely if the gas holder pressure falls below one inch of water.

Preparation of Process Gas (Fig. 2)

One important step in the reaction is to prepare a process gas with the proper hydrogen-nitrogen ratio of 3 to 1 by volume. In this plant hydrogen is used to burn the oxygen from the air, and the resulting water is condensed.

The hydrogen and air to the burner are ratio flow controlled. This ratio is continuously adjusted by a hydrogen analyzer controller which maintains the proper analysis of the gas leaving the furnace. This furnace is used as a waste heat boiler.

The temperature of the furnace is recorded, using an Inconel-Alumel thermocouple. This recorder is equipped with alarm contacts which will shut down the plant completely if the temperature varies plus or minus 20 C. from the set point. This instrument is a safety device to insure the proper operation of the cascade system controlling the air to hydrogen ratio.

The pressure, temperature and dew point of the air, as well as the flow to the burner, are measured to provide data for calculating the pounds of nitrogen used, for efficiency determinations. The pressure and temperature of the hydrogen are also measured.

Compressors

The process gas is cooled and goes to five stage compressors driven by internal combustion engines where the pressure is raised from 2.5 psi. to 5000 psi. The suction pressure is controlled by a pneumatic pressure controller which operates the governor in the fuel gas line to the compressor engine. This pressure controller also has alarm contacts which sound an alarm and shut the plant down if the suction pressure drops below two inches of water. The engine ignition systems are tied into the general shut down system to stop the engines whenever a condition exists which calls for a complete plant shut-down.

Continued on page 176

*Presented at fifth symposium on "Instrumentation for the Process Industries," Texas A&M College, College Station, Texas, Oct. 11-13, 1950.

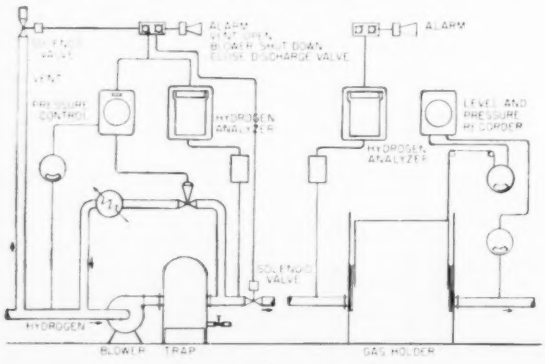

Fig. 1. Hydrogen Collection

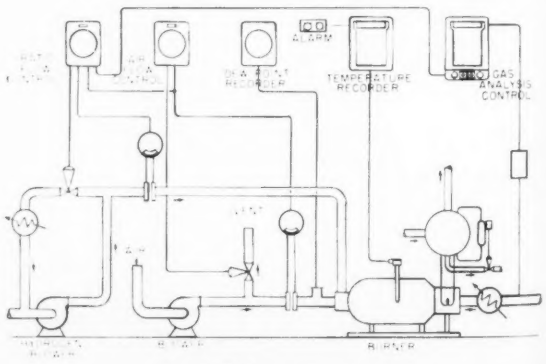

Fig. 2. Hydrogen Burner

A High-pressure Differential Manometer

By MARTIN B. BILES, Assistant Professor of Mechanical Engineering, University of California, Berkeley, California

A HIGH-PRESSURE differential manometer which permits visual observation of the liquid columns is described herein. This instrument was constructed to facilitate the accurate measurement of small pressure drops in fluid meters and hydraulic equipment operating under high flow pressures. It is realized that various mechanical devices, such as bellows type gages or strain indicating instruments, can conveniently be adapted to differential head measurement. However, the accuracy obtainable from such mechanical instruments is generally not comparable to that achieved with a manometer, especially when operation is attempted at high pressures. Furthermore, any secondary measuring element requires calibration against a primary instrument, which may present a difficult problem in itself.

If visual observation of the manometer columns is to be realized the fluid must be contained within glass tubes. The recommended inner bore for glass manometer tubes is one-half inch, or greater. This requirement for the minimum bore size restricts the internal pressure in high-grade Pyrex glass tubes to values less than 400 psi. Irrespective of this pressure restriction, satisfactory manometer operation is not readily attained at high pressures owing to difficulties encountered in perfecting glass-to-metal seals. A major obstacle in the perfection of such seals is the large diametrical tolerances that must be accepted in glass tubing.

The difficulties described above have been eliminated successfully in the high pressure manometer illustrated herewith. The outstanding feature of this instrument is the constraint of the high pressures by a heavy manometer case and tempered plate glass "windows," which permit a direct view of the fluid columns. Such an arrangement limits the pressure differential across the glass tubes and the tube seals to a value equal to the differential head under measurement.

All major metal components were manufactured from high-quality stainless steel to obtain satisfactory strength and anticorrosion qualities. The conspicuous components are the main body, cover assembly, two plate glass windows, two glass tubes, and the necessary seals and fittings. The main body of the instrument was constructed from a solid block of metal of dimensions 24½ x 7 x 2 inches. Two 20-in. grooves were milled in the wide face of this block to accommodate the ⅝-in. straight glass tubes. One groove, that of the low-pressure leg, is equipped with neoprene "O" ring type seals at each end to seal the tube from the body. The high-pressure leg is provided with a similar seal only at the lower end, the upper end of the tube terminating unsealed within the groove. At the lower end of the block a drilled hole, located below the seals, connects the two legs, completing the customary "U" of differential manometer columns. A second internal passage connects the two grooves at a point intermediate between the seals. This arrangement permits the low-pressure gas to act on the fluid in the sealed leg and the high-pressure gas to act on the fluid in the unsealed leg and, therefore, on the outside of both tubes. It is apparent that this instrument is similar in design to the usual open-leg atmospheric manometer, with the pressure acting on the external surface of the tubes being equal to that acting on the open leg. The only pressure differential acting across the tubes, or the tube seals, is that corresponding to the differential head across the two manometer legs, a maximum of 20 inches of fluid (usually mercury).

The external pressure on the tubes is contained by two one-inch thick tempered glass plates, 22½ in. long and 2½ in. wide, to permit vision of the tubes. Sealing between the glass plates and the metal body is accomplished by use of large neoprene "O" ring seals. In order to utilize such a seal appropriate grooves, to accommodate the "O" rings, were milled in the face of the body circumscribing each of the tube grooves. A single cover plate supported both of the glass plates in location. Accurate spacers are installed between the adjacent faces of the cover plate and body to provide the neoprene seals with the specified amount of initial compression. Eighty-one heat-treated bolts of ⅜ in. diameter fasten the cover plate to the body. Some type of soft gasket material must be inserted

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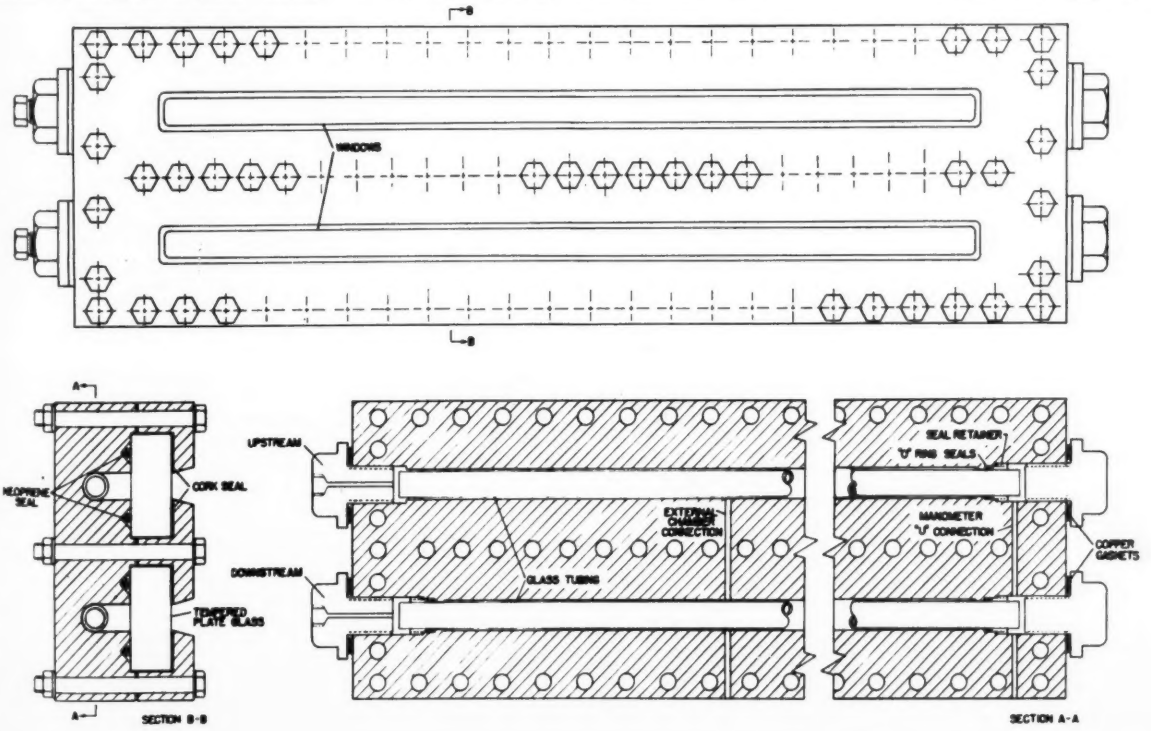


Question *and* Answer Session

at Texas A & M's Fifth Annual Symposium *on* "Instrumentation *for the* Process Industries"

FOLLOWING the presentation of papers at the technical sessions of Texas A & M's Symposium (Oct. 11-13, 1950), a general "question" period was held on the last day of the meeting. Persons attending the technical sessions were asked to submit their questions in written form. At the Question and Answer Session these were presented for answer to the authors. The Texas papers were published in *Instruments* in November and December, 1950 and in January and February of this year.

GRAPHIC PANELS

A. V. NOVAK, E. I. du Pont de Nemours & Company

(Published in *Instruments*, November 1950)

M. K. Andersen (Carbide & Carbon Chemicals Corp.): Why are you so willing to give up graphic instruments and graphic panels?

Novak: This question has come up in the past day or two in off-session meetings. Apparently I did not make my point clear. We are not giving up graphic instruments, we are just consolidating them and relocating them. By consolidation we save space and put them there for reference if needed. Many of the people who are operating the graphics say that for the usual day-to-day operation, they are not needed, but they are there. You need your records for start-ups, for instrument line-ups, where our own instrument people are involved, and for detecting those things that caused upsets in the immediate past. There is also another reason for charts, and that is for supervisory review to find out what the past operating history has been. We are not giving these up, but merely relocating and consolidating them. Graphics are not void of recorders.

Andersen: In order to get records of processes will recorders be required? What cost difference will result to set the controllers and the recorders?

Novak: It is correct in that records will be necessary. Graphic manufacturers state that the cost of the graphic panel, as such, is essentially the same as the conventional type of board. Therefore your saving comes from decreased area and decreased volume of your control room. I cannot give you a specific dollar sign figure on it. The reason I cannot is that a figure holding for the refinery industry will not necessarily hold for chemical or food industry.

Andersen: On your comparison between conventional and graphic panels concerning space, and the initial costs, were recorders included in the conventional space and excluded in the case of the graphic panels?

Novak: The comparison was totaled in both cases.

Andersen: What do you mean by close-coupled loops? What good are they?

Novak: The detecting element, the controller, and the control valve are all physically located in a very small area. The reason being obviously to cut down transfer lags. Mr. Marchment of London cuts the lags down by electrical transmission. Close control loops then are made up of elements that are closely related and physically in close proximity. The second part of the question is, "What good are they?" The whole reason for doing it is to cut down the time constant of your system. This is important in your speed of responses, that is, getting your process to follow your detected error. You find the shorter your time constant is, the better frequency response and the smaller phase-angle shift you run into.

J. E. Saxon (Carbide & Carbon Chemicals Corp.): What type of materials in construction are most advisable for panels that the graphic panel is built upon?

Novak: Basically we have had experience with only one type, the regular conventional steel panel. I understand that one manufacturer is going to a very light panel for their graphic portion of the board. The reason is ease of modification in case modification is necessary. There are people that make panels of ebonite board, a very heavy board. I believe that you have to match your particular requirement. The graphic, I believe, is flexible and can take almost any type of material and construction that will stand the physical weight that is involved. I would say the weight is comparable to a standard board or somewhat lighter.

Andersen: Why not combine the console and graphic panel?

Novak: That has actually been done in several cases. A console has been located in the center of the graphic. The graphic is a tool flexible enough to meet the wishes of most people.

W. T. Marchment (Evershed & Vignoles Ltd.): When you referred to the combination of the console and graphic panel, did you consider the mimic diagram a part of the control in the way you mentioned above.

Novak: The combination graphic and console that I have in mind employs the conventional graphic as part of the regular control system. When a console was located in the middle, it was used merely as a logging center and a place for collecting data such as one would collect off of a multi-point indicator. If I interpret your question correctly, you ask if the pictures you had on the screen yesterday can be considered a graphic. Is that your question? Yes, I would say it is a combination. It approaches very closely a certain form of graphic that is on the market today. There are certain advantages of this system, but also some disadvantages. I would like to answer your question with a return question. What do you do when such a system needs 50, 60 or 70 controllers. As I remember, that system involves only 19 controllers as such.

Marchment: This is where the inherent flexibility, with all due respect to mathematics enthusiasts, results in simplicity. With reference to Mr. Novak's 70 or 80 controllers, presumably what we could do would be to put cubicles each containing 30 controllers, say 4 banks of them, making a total of 120 controllers in a small room. The correction from the controllers could be brought out to control knobs mounted on graphic panels or desks in the main control room. It is important to bear in mind that the emphasis in this development is not so much in the representation by means of a mimic diagram or picture as the ability to house controllers and control panels conveniently in the minimum of space.

Marchment: Is it considered that there is any advantage in having the controllers inside the control room where they are under proper attention as against having them outside on the pump.

Novak: The advantage of working on the controllers in an air-conditioned control room versus working on them in the field cannot be denied. It is a matter of having to choose which 2 situations are of greater advantage. In a pneumatic system, the advantages to be gained by close-couple control systems must be weighed against this decentralization of control units. In the cases where the answer comes up such that there is little to be gained, naturally the controller should be in the control room and the graphic panel allows for that. It can be so located. Where advantages of close-coupled systems and decreased time constants in the system are desirable—they are always desirable—but when they have a controlling effect, then it

is a cheap price to pay to actually locate your controller where it is needed. I am speaking of pneumatic systems, and not of electrical transmission systems.

CONTINUOUS ANALYZERS

Dr. B. W. THOMAS, Humble Oil and Refining Co.
(Published in *Instruments*, November 1950)

M. K. Andersen (*Carbide & Carbon Chemicals Corp.*): Is there an instrument available for sale for continuously recording H_2S content down to ¼ grain per 100 cubic feet in a dry hydrocarbon gas, if so what principle is employed?

Dr. Thomas: I am not sure exactly what part per million that would be. I do know that there is an instrument available, not for purchase but for rent from Consolidated Engineering Corporation which employs the principle of titration. It will determine to as low as one part per million, and it will record continuously total reactive sulphur or it can be arranged to measure total H_2S, total SO_2, or mercaptan sulphur.

Andersen: Please comment on safety features concerning continuous analyzers.

Dr. Thomas: Instruments can be placed in hydrocarbon atmospheres or in explosive areas but provision must be made for making those instruments safe. Some instruments that I listed are available in explosion-proof housing. Another thing that should be considered is the fact that hydrocarbons passed continuously to an analyzer should not be permitted to enter a control room in which there is considerable equipment that is not explosion-proof. Ordinarily, our recording type instruments are not explosion-proof, therefore it is certainly not advisable to permit hydrocarbon streams to be passed to an analyzer in a control room. In other words, it is best to locate the analyzer outside the control room and place it in an explosion-proof case.

Andersen: Please comment on the economics of continuous analyzers.

Dr. Thomas: My comments concerning economics will not concern a particular type continuous analyzer, but instead will be directed at continuous analyzers in general. Some study of the credits that are accruable to uses of several types of instruments has been made. There is a general indication that for every dollar spent for continuous analysis instruments, a return of about three dollars per year thereafter is realized.

J. R. Parsons (*Phillips Petroleum Company*): With regard to your remark that the dielectric constant of the polar compound and the hydrocarbons are not added in linear fashion, can you calculate the dielectric constant of such a mixture, knowing the respective dielectric constants?

Dr. Thomas: It is not easily calculable but it can be measured.

Parsons: I would like to ask the effect of the water droplet size and the shape of the dielectric constant of the water or emulsion; I am thinking of the water concentration from 0.1 to 1 percent.

Dr. Thomas: I think I have the question fairly well in mind, concerning the use of dielectric constants in measuring low concentrations of water in hydrocarbons. Certainly if the measuring element is so small that the water droplets bridge across the plates of the condenser, the instrument would not function properly because a shorted condition would exist. The problem of applying dielectric-constant measurements for the determination of water or alcohols in hydrocarbons is something that has not been developed satisfactorily to date. The difference in dielectric constant between water and hydrocarbons is quite large—and because of that you would naturally think that such a device as we are discussing would be good for measuring low concentrations of water and hydrocarbons, but it does not appear to be as good as theoretical considerations would indicate. Before one can say very much authoritatively on this they will have to do a large amount of experimental work.

Dr. J. F. Draffen (*University of Texas*): In your paper, you mentioned microwave spectroscopy. I would be very much interested in any comment you would care to make on the application of this method to continuous analysis. For example, what compounds might be detected? Could the method be used for both gas and liquid streams? How complex would the equipment have to be?

Dr. Thomas: Let me say first that our knowledge of the application of microwave spectroscopy to even laboratory studies is certainly very limited to date. We do have quite a few laboratories throughout the country developing microwave equipment but to date it has not been applied too satisfactorily in the laboratory for the analysis of either chemical or petroleum materials. I mentioned that as a possible future development for continuous analyzers, but certainly we must study these instruments in the laboratory first and prove that there is a measurement that means something before we can think of developing continuous analyzers. As to the types of compounds that can be detected by microwave spectroscopy, I pointed out polar compounds primarily. These are compounds in which oxygen, nitrogen, or sulphur may be contained. The microwave absorption in hydrocarbons is relatively small. That is, hydrocarbons do not absorb microwave energy near to the extent that they absorb infrared energy.

W. M. Sloan (*E. I. du Pont de Nemours & Co.*): Describe the principle of intensity technique in the measurement of refractive index.

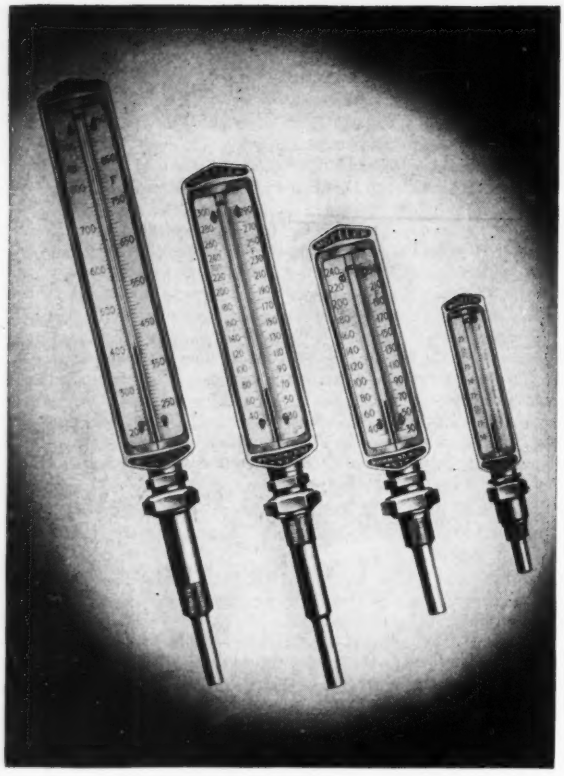
Dr. Thomas: I did not describe that particular instrument because certainly the time we had here was not sufficient for describing all possible types of instruments. I merely mentioned that there is a refractive index instrument based upon the reflected intensity of light between the medium of a material under test and the medium of a prism. I pointed out the advantage of reflection-type over transmission-type refractometers; pressures can be withstood and materials that are not transparent can be measured for refractive index. The instrument is essentially a compartment in which light is passed through a prism to the interface between the prism and the material under test and the intensity of the reflection is compared with a reference intensity beam. Photoelectric tubes are employed for measurement of the intensities. Of course, the light intensity is easily converted into electrical energy for measurement.

Andersen: Just wherein does it become difficult or impossible to predict the application of infrared analyzers?

Dr. Thomas: If there are three materials in a stream in which an analysis is desired for one of those materials, a non-dispersion continuous instrument is applicable to that analysis only if the infrared spectrum of the one component is not over-shadowed by the combined spectra of the other two components. If that difference does not exist, then the analysis is not possible, but one generally finds that there is some difference between practically any one of 3 component hydrocarbons in mixture. The extent to which non-dispersion instruments can be applied has not been explored. This field of analysis is a relatively new science, and it has been carried on very largely on a trial and error basis to date.

Andersen: If the infrared absorption properties of all the gases involved were known, could you determine then that you had enough power to be picked up by some infrared detector? Is there a minimum amount of infrared radiation that you would need in order to detect that?

Dr. Thomas: I could not say in terms of the microwatts of energy required for an analysis because that factor is not very well established in infrared technology. It is always possible, of course, to get an infrared spectrum of any gas by running it on a recording percent transmission infrared spectrometer. We take these patterns and study them for the components expected in the mixture to be analyzed; if the spectra are quite similar then the possibility of applying a non-dispersion instrument is less. The greater the dissimilarity, the greater the possibility of this detection. In the past few years considerable progress toward building sensitive amplifiers for increasing this small difference to a measurable extent has been made, and I do not think that we have reached the limit by any means yet;



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that is the instrument manufacturers have not reached the limit toward which they can amplify a very small sample into a measurable quantity.

Andersen: Can you chart the pattern of infrared absorption properties and arrive at any conclusion from that? In other words, is there a scale there that you can use or is that a variable scale that can measure the available infrared absorption?

Dr. Thomas: The question is can you look at the spectra of these pure compounds and tell whether or not any one can be measured individually in a mixture by means of a non-dispersion analyzer. You can get some idea as to whether or not your non-dispersion analyzer will apply. We know that towards the short wave length end of the infrared spectrum we have by far the most energy, so if the difference occurs in the long wave length region the chance that this instrument will apply is less than if the difference occurs where the high energy is present. In some cases very good indications of success are obvious; in others it becomes doubtful and the only final test is experimental data.

Andersen: Referring to the infrared analyzer again, would you comment on the effects of ambient temperature, rate of sample flow, pressure, and so forth, other factors and their relative importance?

Dr. Thomas: We know that all of these instruments depend upon a temperature change in the detecting system for the measurement, so if ambient temperature is changed that will certainly upset the measurement. That is especially true for the bolometer or thermopile-type detectors. It is not as effective in the acoustic-type detectors. Pressure does affect the infrared absorption in non-dispersion instruments and should be controlled rather carefully. It is necessary to keep the sample flow rate practically constant. In other words, the pressure within the sample cell should remain constant. The absolute pressures that can be tolerated in a non-dispersion analyzer depend upon the type gas cells employed. If the cell is made of rocksalt windows, a pressure much above one atmosphere cannot be tolerated. However, the Bureau of Standards has recently announced the production of a rocksalt-windowed cell in which the pressure may be as high as 30 psi. They have actually analyzed butane in a liquid state in cells of that type.

R. C. King (Dow Chemical Company): Will the presence of water in a mixture of hydrocarbons mask the dielectric variations between materials sufficiently to make the method unsuitable for analysis, the water content being below saturation?

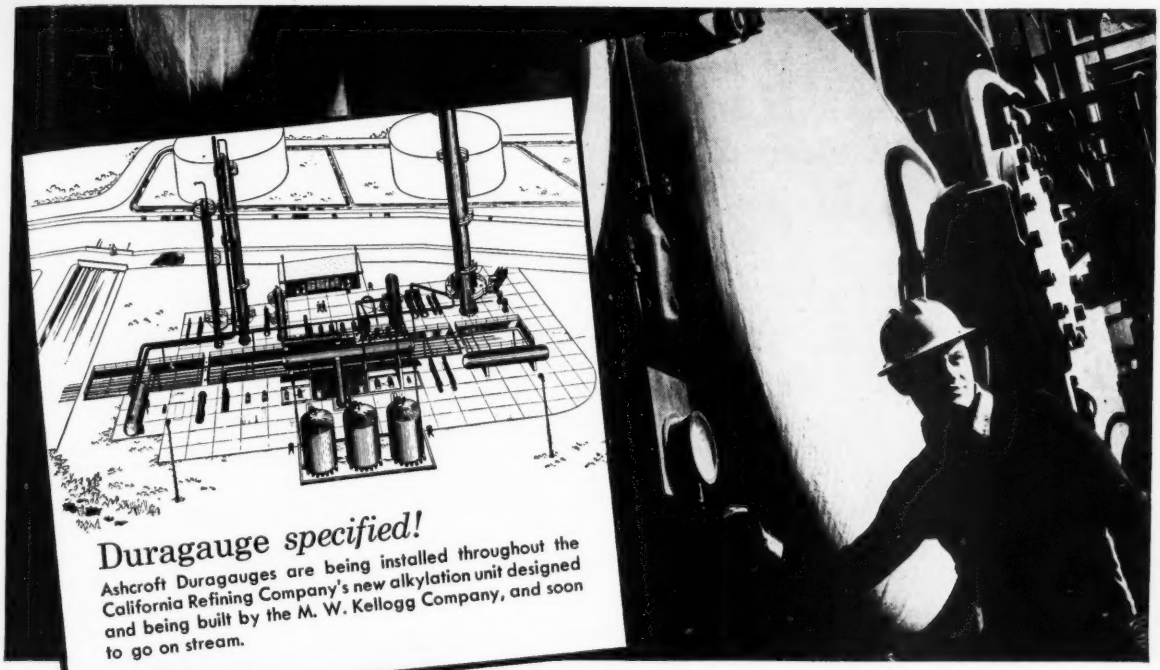
Dr. Thomas: That the effect of water on the dielectric constant is so small up to the saturation point and the difference is so large between types of hydrocarbons that low concentrations of water, that is, below saturation, would not affect the measurement of one component over the other. If the water content gets high enough, you may have droplets large enough to bridge across your dielectric condenser. Then the analysis is no good.

R. E. Hansen (Leeds & Northrup Company): Would you comment on the sensitivity with respect to the percentage of the gases contained?

Dr. Thomas: I do not know the whole story on infrared continuous analysis work, but I do know that in most cases applications are made in which small components are measured and over fairly wide ranges of small concentrations, sensitivity is very near linear with concentration. That is known to be true for some applications. One would not be wise in trying to measure isobutylene or ethylene in concentrations as high as 95 to 100 percent. For instance, instead of looking for the ethylene, they would look for the contaminants.

P. A. Buckley (E. I. du Pont de Nemours & Co.): You mentioned a continuous mass spectrometer for process rings. Can you say whether it can continuously analyze the gaseous hydrocarbon streams or more components?

Dr. Thomas: The instrument to which I referred is manufactured by Consolidated Engineering Corporation. It is called a process control mass spectrometer. To date, it is



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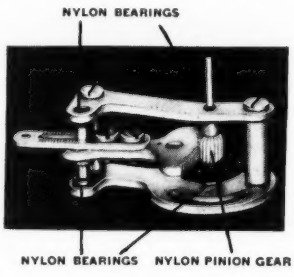

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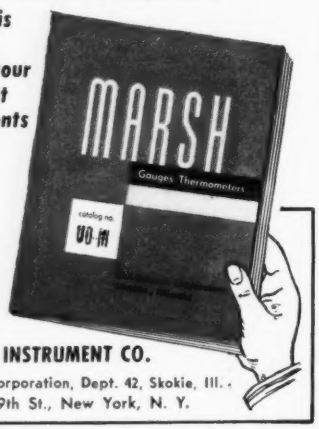

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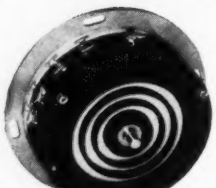

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equipped for recording consecutively three masses. It may be possible to rearrange whereby it might record consecutively four masses. These are pre-selected masses and they would not necessarily be adjacent in a mass spectrum, so it is possible to look at more than three components. Of course, what you do is look at the total ion current at one particular mass, and that total ion current might not be representative of that one component only, because there is always interference. One can tell by the general increase or decrease of that particular ion as to whether or not the major contributor to that ion is increasing or decreasing.

SPEED CONTROL
and Synchronization of Multi-unit Internal Combustion Engine Plants

H. C. GIVENS, La Gloria Corporation

(Published in *Instruments*, December 1950)

L. A. Larrey (*Carbide & Carbon Chemicals Corp.*): What was the purpose of the motor valve in the suction line?

Givens: In casing-head gasoline plants, oil operators producing oil wells operate their separators as near atmospheric pressure as possible, especially when they have a plant to which to put their casing-head or separator gas. The compressor plant is usually designed for the compressors to take suction somewhere around 10 lbs. absolute. The pressure coming in from the field varies considerably over just an hour's time. The pressure on the field line may vary from 2 in. vacuum to 10 lbs. pressure. Rather than take that variation on the suction of the compressor, the pressure regulator is installed, reducing the pressure to hold a constant pressure on the suction of the compressor cylinders.

R. Webb (*Carbide & Carbon Chemicals Corp.*): Why control the suction pressure by varying the speed of the engines and have the reducing regulator to hold the constant pressure on the suction of the engine?

Givens: If you will refer to Fig. 1, the pressure controller was connected to the upstream side of the reducing regulator, and we want to control that upstream pressure as near as possible to atmospheric pressure. We speed the engines up and slow them down with the variations of this upstream pressure.

Webb: I think this is poor economics. Why do you take that loss in the suction? Why don't you design your compressors to take the higher suction pressure, or were you planning that for some future time when you have to pull that pressure down?

Givens: That is part of the reason. Another reason is the lower you can hold your field pressure, the more money you make from the gasoline which you make from your gas. A lower separator pressure pulls a little more of the lighter ends out of the oil before it goes to the storage tanks where the lighter ends would weather off in any condition. We actually hope that in time we may be able to eliminate the reducing pressure regulator, but at the present time our compressor capacity is not keeping up with the field output, with the railroad commission increasing allowable production days and drilling of new wells, and the delivery of engines becoming longer. Some point has to be decided where to hold the constant pressure on the suction of the compressor cylinders, and they had to be purchased for the future rather than the present operating conditions. Compressor cylinders are quite an expensive piece of equipment, especially when they get up as large as 30 in. in diameter.

W. H. Fortney (*Humble Oil & Refining Co.*): Can the loading of the engine be accomplished better by control of manifold pressure?

Givens: There is no way of controlling manifold pressure on a two-cycle engine because they have no manifolds. Practically all engines, I will say 99 percent of the engines in casing-head, cycling, and similar work, are now 2-cycle engines, and they are becoming more so. The old disadvantage of the 2-cycle engine being a high fuel user has now been overcome. With a 4-cycle engine, a fuel consumption of approximately 9½ to 10 cubic feet of gas or 10,000 Btu per horsepower hour is still the rule. Some of the newer 2-cycle engines, Clark, Cooper-Bessemer, and a few

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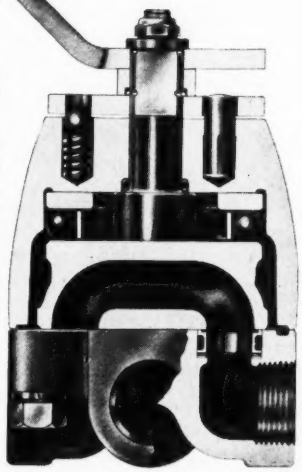

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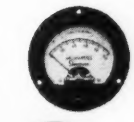

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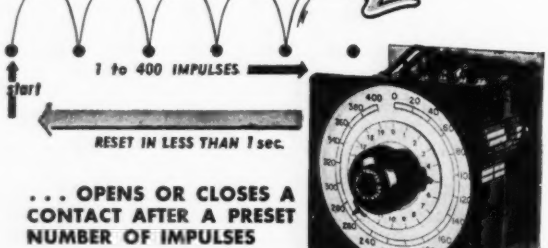

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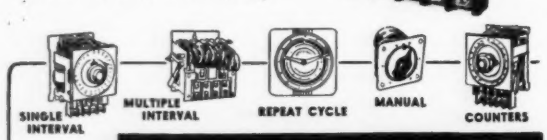

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of the other well known 2-cycle engine manufacturers are claiming as low as 6500 Btu's per horsepower hour consumption. So as that becomes generally known and people take that into consideration, I believe that the 2-cycle engine is going to be more and more used. That is one of the main reasons I didn't touch on control by manifold pressure.

L. C. Books (Shell Oil Company): What type of a motor valve is used in the suction line for pressure reducing?

Givens: That is an R-S butterfly with a Taylor top works and valve precisor. It is being controlled by a Moore transmitter transmitting the pressure to a Taylor receiver recorder-controller.

W. T. Marchment (Evershed & Vignoles Ltd.): There is a drift or integrating effect of the mechanical differential unit in speed control against the electric control. What effect or accuracy is found of this?

Givens: I personally have not used any of these differential control systems. The man that is operating the Synchro-master unit told me than an engine speed-up being required, all engines would be in synchronized speed and phase of crankshaft angularity within a very few seconds. In his work it didn't make much difference.

Elmer Kleir (Foxboro Company): If the engines become supercharged, can you anticipate any trouble in speed control of those engines?

Givens: Right at the moment our place is installing our first supercharged gas engine. I conferred with the manufacturers considerably on that and they said that the old, simple first type that I showed you was going to operate much better on supercharged engines than on the old, ordinary 2-cycle engine (unsupercharged and not high compression). I have yet to discover whether or not that is actually a fact.

M. K. Andersen (Carbide & Carbon Chemicals Corp.): Can you justify a phase control on engines purely from an economic consideration?

Givens: Never having operated engines on phase control, I cannot answer that only in what I am told by people that have. They say it definitely reduces maintenance costs in the engine plant, due to dampening out vibrations, especially when there is a tendency for them to get into harmonics. Also on a high-pressure compression plant, as an example, where we have eleven 800-hp. engines having 44 compressor cylinders, compressing gas from 1,500 to 3,000 lbs., there is a definite pulsation problem in measurement. You must go to quite considerable expense if you expect to get a decent measurement. We have neither gone to that expense, nor are we getting a decent measurement. People who have used this phase control say that when they run compressors in an angular phase control of crankshafts, it definitely helps eliminate the pulsation, and in a great many cases they need no other pulsation dampeners to smooth out the flow.

H. L. Bowditch (Foxboro Company): Is the power of the engine itself used to drive the motor that controls the differential unit or the differential speed?

Givens: It has been tried. However, usually in cases where they have this control they want to save all of the power of the engine that they can for emergency cases, especially in a case where 800-hp. engines are running at 875 hp. most of the time.

Andersen: Why do you not install a motor valve in a fuel gas line for the engine instead of having the diaphragm-motor valve setting the governor?

Givens: It is due to sudden demands of a rapid load change. However in gas compressor work, it is feasible, I have found out recently, and certain people are doing it. It is feasible although the engine people will tell you that it is not. In casing-head gasoline and cycling plants the load does not change very rapidly. It will take several minutes for the pressure to build up from zero pressure to 8 lbs. or go back from 8 lbs. to zero. Therefore, in cases like that it is entirely feasible to control direct instead of through the governor.

Webb: What happens to the Synchro-master during start-ups or at other times when the compressors are well out of synchronism?

Givens: There is a switch on each panel to take care of that, but if you bring it in on manual it approaches a synchronized speed then you can switch it on to automatic and it takes care of it. That switch is hooked in, in such a fashion that when the engine dies for any reason, to keep from wrecking the rest of the machinery, it will automatically switch over to hand operating point.

A NEW CONCEPT of Automatic Control

R. E. CLARRIDGE, Taylor Instrument Companies

(Published in *Instruments*, December 1950)

O. K. Wetzel, Jr. (*Magnolia Petroleum Co.*): Is the new proportional band composed of two factors—the sensitivity (S') and the gain (n), the product being equal to one-third of the sensitivity in the former controller?

Clarridge: On the last illustration in the sequence there were two proportional bands shown, one of which was narrower than the first. The one-third factor applies to the over-all sensitivity and gain (nS').

J. C. Riedel (*Oil & Gas Journal*): Was there any connection between this development and the graphic panel story?

Clarridge: Yes, but purely a commercial one. At least as far as I know, the first instrument which has incorporated this type of control system happens to be one which fits in beautifully with graphic panels. As it is being introduced at the present time, it probably can be used more easily with graphic panel instruments than with the more conventional controllers.

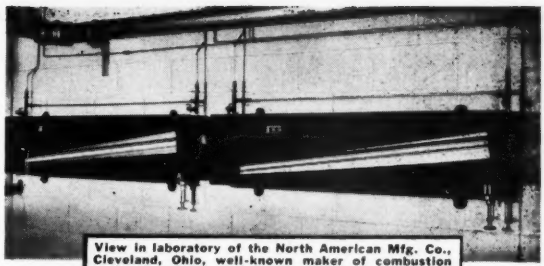
R. D. Webb (*Carbide & Carbon Chemicals Corp.*): What is your feeling about the use of derivative on flow control?

Clarridge: There is nothing that rules out the use of this type of control system on flow, but due to the nature of the previous derivative responses available in conventional controllers, it has sometimes been arbitrarily stated that derivative is not applicable to flow control. The new control circuit, coupled with a broader range of adjustment of the derivative action, enables the derivative effect to be used on flow controllers. In fact an actual installation has been made with a flow chart which opens up the time scale. This new control system with derivative action limits the deviation and brings the flow back to the control point more effectively than the conventional controller. Thus the new control system with derivative action is very satisfactory.

Then why, you might say, should we use this type of control system, since we are very well satisfied at present? The major reason is that the set pointers of flow controllers are moved more often than those of other controllers in the plant. It is very nice to have the flow move upward or downward on the chart and round into the control point without overpeaking. Pneumatic set flow controllers which respond to another variable often move the set point of a flow controller through a considerable distance. Again the new circuit produces more stable performance. Therefore, it is my feeling that the derivative and the new control circuit will have quite a wide use in flow controllers.

R. B. Gray (*American Meter Co.*): Why not put the derivative into the transmitter, transmitting it over to the receiver, and thereby remove the lag in transmission before it gets to the receiver?

Clarridge: This is satisfactory if the lag is primarily in the measuring element and the transmitter. Note that on the receiver you will obtain a corrected record which eliminates those two lags. Actually transmitters have been designed with that feature, but I am not as familiar with them in the flow field as in the temperature and pressure field. One difficulty which I can see with this system is that if there are other lags in the circuit, these cannot be adequately handled by the derivative without destroying the value of the record. Another difficulty is that there is trouble enough damping out a flow meter in order to get a reasonably stable record, so one might question the merit of adding derivative to a transmitter which will cause greater variations on the record. It seems to me that a



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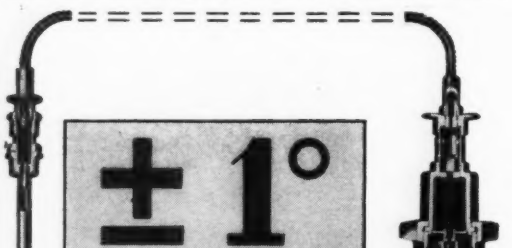

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better solution is to put the derivative in the controller so that a corrective valve action can be obtained, but to record an average of the variable flow. A record of this type is easier to read and to integrate.

M. K. Andersen (Carbide & Carbon Chemicals Corp.): Is it easier to arrive at optimum settings with your proposed system than with the conventional pneumatic system?

Clarridge: It is much easier to arrive at *satisfactory* settings. It is questionable whether it is easier to arrive at *optimum* settings because the controller is much less sensitive to changes in the settings. You will recall that in the equations covering the new control system we eliminate the (1-RT) in the denominator. Therefore, changes in the values of R′ and T′ in the new controller do not cause as much change in the value of the over-all sensitivity as corresponding changes in the value of R and T in the conventional controller. Therefore, while optimum settings may be just as difficult to obtain, their importance does not seem to be as great.

Andersen: How would you apply the proposed control system advantageously to a control system which includes pressure control setting a speed control for a gas engine?

Clarridge: That in particular is one of the applications on which this new controller should show its greatest merit. Speed control is notoriously difficult due to the rapid responses which must be obtained. Those of us who have tried to substitute instrument-type control for the hydraulic-governor-type control have found that difficulty is encountered in picking up the load changes fast enough. This new control system as available in the first commercial design can be closely coupled to the engine so that improved results can be expected. Of course, the new control circuit is advantageous because of the start-up problems characteristic of gas engines.

Andersen: Did you say when R and T are equal the true sensitivity approaches infinity?

Clarridge: I believe that I did, but I should have said that when the two *restrictions*, derivative and reset, are equal the true sensitivity approaches infinity. This is equivalent to saying in the equations that the product of $RT = 1$.

Andersen: Whereas your new controller stresses derivative, will it still function as well as a conventional controller if a derivative is not employed?

Clarridge: Yes. If a derivative is not employed, the new control system behaves like a conventional controller. It will be noted from a study of the equations that they become greatly simplified when derivative is not used.

UNBALANCED FORCE REACTIONS in Control Valve Plugs and Their Influence on Diaphragm-motor Design and Operation

R. A. ROCKWELL, Mason-Neilan Regulator Co.
(Published in *Instruments*, December 1950)

J. M. Jones (Texas Co.): If there are advantages to reversing the flow through valves, why isn't it done more extensively?

Rockwell: When the flow is reversed through a double seated body, the inlet or high pressure is under the packing box and some people dislike this arrangement. With the flow through the body in the normal manner the force is tending to open the valve at the closed position. This force is due to the difference in areas between the two seats, multiplied by whatever differential pressure exists in the body at that condition. Those forces are relatively small. A 4-in. parabolic plug with a 100-psi. drop has a force at the seated position in the neighborhood of about 50 lbs. A 4-in. valve normally has a diaphragm area in the neighborhood of 100 square inches. This force represents 0.5 psi. diaphragm pressure. This is not a very serious force to contend with, whereas the same parabolic plug as it approached a maximum lift had an unbalanced force close to 500 lbs. That is equivalent to 5 lbs. pressure on the diaphragm and is quite substantial. Again, we are only talking about 100 lbs. pressure drop. The picture in the valve industry has changed quite appreciably in the last 15 or

20 years. Fifteen years ago, a customer's specification for an 8-, 10-, or 12-in. valve indicated that it would be used on low-pressure exhaust steam or water to the cooling tower. But today people buying valves have no scruples about specifying 8-, 10-, 12-, or 14-in. valves and expect them to stand up and take 400 or 500 lbs. pressure drop.

Jones: What is the possibility of using a quick-opening double-seated valve in place of the parabolic and sacrificing the percentage characteristics for those of a quick-opening disk?

Rockwell: I have deliberately tried to avoid talking about characteristics. By so doing I am observing a request of the Steering Committee. It is an extremely confusing subject, and I know no way of simplifying it. I think there are lots of applications where characteristics are relatively unimportant, and if you can gain the advantage of reducing unbalanced forces by the use of quick-opening disks, I see no objection to this procedure.

C. W. Bates (Humble Oil & Refining Co.): Have you done any work in measuring the unbalanced forces with angle-type valves?

Rockwell: Yes, we have made quite an extensive study, first from a mathematical approach and secondly plotting curves to predict the force behavior. In actual test work we have tested small-size angle valves on water (up to 2-in. sizes) with pressure drops of 800 psi. We have never done any testing on compressible fluids on angle valves. The general character of the force curves on angle valves are very similar to those shown on the parabolic valve. The great limitation on all angle valves is that the flow is brought in over the seat. This arrangement develops a slamming characteristic and an accumulative action which tends to make the valve unstable. It is unfortunate that there is not some nice compromise, because there is much to recommend the angle valve and its free flow characteristics. It is a very efficient valve as the angle valve runs in efficiency up to almost 99 percent efficiency.

Bates: Was there a reversal in force reaction on the angle valve?

Rockwell: There is no reversal in the force direction.

R. Givens (LaGloria Corp.): Were the tests that you have run on springless motors on diaphragms or piston designs?

Rockwell: We have tested single-seated valves both with springless diaphragm motors and with the piston operators. One thing that we did with the piston operator was to take the 4-in. valve and bring the flow in over the seat. We adjusted the piston operator so that at the seated position the volume on the underside of the piston operator was very small, and we hoped to see if there would be enough compressibility in the lower section of the piston operator to give it some stability. But, as far as we can determine, we were unable to develop any indication that pulling the piston down to compress the air underneath the piston of even a very small volume added anything in the way of stability. As a matter of fact, the strain gage unit had an uncut machine thread. We didn't discover it until we were testing the 4-in. single-seated-valve piston operator, and when the plug hit the seat we broke the strain gage unit.

C. F. Woods (Minneapolis-Honeywell Regulator Co.): Was any study made of rotation forces on your angle-valve tests?

Rockwell: No, we have never made any tests of rotational stem forces on the angle valve. We have tested rotational forces on the parabolic plugs, quick-opening disks, and a wide variety of skirt-type valves.

H. E. Wright (Jefferson Chemical Co.): Has your firm done any test work where the flow through the body has been reversed on bellows-sealed valves, and did the forces presumably caused by the pressure in the bellows cause any appreciable deviation from the normal curves?

Rockwell: No, we have never made any special attempt to analyze the force behavior with bellows-sealed diaphragm valves, but I am quite sure that we could predict that be-

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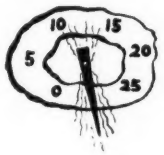

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yond the simple alteration due to the increased effective area of the bellows with respect to the area of the stem, that there would be a base shift of the unbalanced forces and the change of force with respect to lift would not be changed.

W. O. Suydam (Cities Service Oil Company): Will you please elaborate on what has been done and is being done on streamlining control-valve bodies to cut down erosion of the internal surfaces of the body?

Rockwell: This is usually a problem of streamlining the body so as to increase the efficiency. Possibly you have seen valves in cutaway sections showing the streamlined characteristics by passing colored smoke and colored vapors through the passages. You can note the smooth, streamlined effect as the smoke drifts through. In actual usage we are confronted with valves in many instances absorbing high pressure drops. With high pressure drops and high body velocities the fluid stream is turbulent. There is some indication that it is not always desirable to have streamlined bodies. This may be true, particularly on liquid service, where streamlined bodies and very smooth flow passages may increase cavitation and contribute materially to erosion.

L. C. Books (Shell Oil Company): Please comment on the effect of characteristics and the drop in the body of the valve.

Rockwell: The question is to comment on the effect of valve characteristics when the drop in the body of the valve is considered. The drop across the port and the drop across the valve body itself are in series, and it is the ratio between the two that requires consideration. As the body comes in to be more of a restriction to the flow, then it is necessary for the port to give up more and more drop because it is the port of the valve that is giving up drop to the body and to the line. One of the difficulties is that you finally reach the limit as to the rate that you can increase the port area of the valve. We can increase the rate of opening up the area to the point that we must lift the plug out of the seat. At this point we approach the maximum rate at which we can expose the port area. These factors must also be given quantitative consideration with respect to the maximum capacity of the valve.

R. H. Putnam (Shell Pipe Line Corp.): How do you predict the unbalanced forces will vary with pressure-drop changes?

Rockwell: The only exact information I have is through the range that we tested, in the range of 85 to 90 psi. All of our curves were plotted on the basis of 100 psi. What we did was to run a series of tests with different lifts and at different pressure drops to correlate the information so that through the ranges which we used our assumption we found that the unbalanced forces were practically proportional to the pressure drop. Angle-valves tested at 800-psi. drop appear to confirm this assumption.

Andersen: What effect would flashing of a liquid to vapor and passing through a control valve have on the unbalanced forces acting on the valve plug which you discussed in your paper? Can you make any allowance for that?

Rockwell: There are many things we do not know when it comes to the flashing of fluids in control valves. Practically the only way we operate is by playing safe and using expanded bodies. How flashing affects unbalanced force reactions is really beyond our scope at the present time. To date, our testing has been for the most part restricted to liquids and we hope to do more with compressible fluids later. The transitory conditions from liquids to compressible fluids is something for much later consideration.

Pete Knapp, Jr. (General Tire & Rubber Co.): Is the use of a valve positioner a solution to the problem of the unbalanced force in ordinary control valves?

Rockwell: The positioner does not eliminate or alter the unbalanced forces produced by velocity effects in the body of the valve. The positioner applies to the diaphragm case the pressure required to force the valve plug into the position corresponding to signal received by the controller. It is frequently possible to increase the supply air pressure to

the positioner and in this manner increase the power of the diaphragm motor to overcome the unbalanced force of the valve plug. In any case, consideration must be given to the force direction of both the plug and the motor operator.

POWER PLANT CONTROLS

B. F. HEYE, Central Power and Light

(Published in *Instruments*, January 1951)

Heye: Some one asked what throttling pressure we maintain at Corpus. We have two pressures in the Nueces Bay station in Corpus. The first four units which consist of 45,000 name plate rating, we maintain at the throttle 375 lbs. That is the manufacturer's plate rating on that. We operate three of those units at 825 F. and one unit, which is a 7500 kilowatt, is rated at 700 F. We operate a new turbine at 900 F., 850 lbs. We are not operating in that range, not that low. We are operating somewhere around 12,000 Btu. kilowatts.

SOME DEVELOPMENTS in Electronic Instrumentation Including Process Control

W. T. MARCHMENT, Evershed & Vignoles, Ltd.

(Published in *Instruments*, January 1951)

C. F. Woods (Minneapolis-Honeywell Regulator Co.): Have any motor-operated valves been used with this equipment?

Marchment: In the early days on our own pilot plant we did use a motor-operated valve in which a contact was made starting a motor in either clockwise or anti-clockwise direction. To overcome troubles such as overshoot, however, and obtain smooth control a motor-operated system having servo characteristics should be used: for example, feedback proportional to speed etc. Although we are electrical engineers we have converted to air at the control valve. The reason for this is a practical one, for while we are large makers of electrical motor-operated servomechanisms, we cannot envisage at the moment such units being provided at as reasonable a price as the air diaphragm motor.

J. P. Swint (Humble Oil & Refining Co.): Is any trouble encountered with voltage regulations with these servomechanisms?

Marchment: The transmitter circuit is such that readings are independent of large voltage fluctuations and variations in line resistance. Under such conditions balance is disturbed and the pot coil deflects causing the grid contact to touch the appropriate bias contact until balance has been restored and the grid contact is floating in the neutral position. In addition, to safeguard against very sudden fluctuations in voltage such as are experienced in Steel Works, advantage is taken of negative feedback and any small change in plate current varies the relationship between grid and cathode voltage tending to stabilize the system. We have to take into consideration on long-distance transmission where pumping stations are being automatically controlled, the change in line resistance. Our own Post Office Authorities do not hesitate to alter the line route in cases of emergency, and line resistance may suddenly vary from 500 to 1000 ohms and control of the plant is expected under the changed conditions.

J. M. Jones (Texas Company): Is there any trouble encountered due to the change in temperature of the springs which are used to balance the force of the torque coil?

Marchment: With the range of temperatures on the plant where we have applied this equipment we have not experienced any difficulty. I think we could provide compensation in extreme cases which is possibly what you have in mind. One thing that would help us in such cases would be that with current torque-balancing devices operating on the null-point principle compensation may be achieved in a simple manner.

C. W. Bates (Humble Oil & Refining Co.): Explain how the mechanical indication was obtained on the flow meters.

Marchment: Mechanical indication is obtained by a fol-

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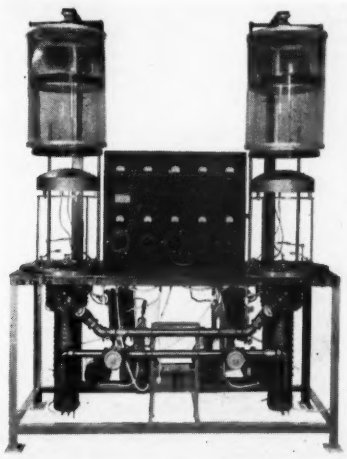

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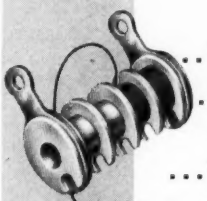

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lower magnet which is acted upon by the north pole edge of the rolling magnet. That is to say, whereas the repulsion force between the rolling magnet and strip magnet of the electrical transmitter is opposed by a force due to current in the pot coil, for mechanical indication one edge of the rolling magnet is used to operate a pointer which follows it.

Dr. J. F. Draffen (University of Texas): How are your time constants of 50 minutes obtained?

Marchment: The integral time constant of 50 minutes is obtained by using an emissive type of photoelectric cell current bridge arranged to charge a capacitor. Unlike an impedance bridge the current charging law is linear. With an emissive cell emission is proportional to the light intensity and the electrons may be likened to cricket balls being fed to a vessel, the storage vessel in the integral circuit being the capacitor. The capacitor value is approximately 24 microfarads. The derivative capacitor can of course be much smaller, and it is interesting to note that the derivative component is added to the integral component, one tube being used for both components. This illustrates the flexibility obtainable by the use of current measuring circuits.

Porter Hart (Dow Chemical Co.): Is this method of measurement applied to temperature measurements as well as pressures and flows, the temperature measurements being made by thermocouples or resistance thermometers?

Marchment: As far as temperature is concerned we are trying out a method which uses apparatus a little different from the one described. As an interim step we are using a potentiometric recorder operating a force-balance transmitter to obtain a current proportional to temperature. This current is fed into the controller circuit.

M. K. Andersen (Carbide & Carbon Chemicals Corp.): In the electrical system described are the 3 settings, proportional band, reset, derivative, entirely independent from one another? If so, could you explain in some detail.

Marchment: In pneumatic devices mechanical link motions are used, for example to connect proportional and integral or reset actions. Summation, subtraction, division, etc. can be achieved electrically without mechanical interconnection and each function can be analyzed independently. Thus the integral or automatic reset current is added or subtracted from the current representing the quantity to be measured, and so also is the derivative current. Each function is separate and therefore there is no interaction between them and the adjustment of one function does not upset the others. That is what we mean by the 3 terms being entirely independent.

Andersen: Would you kindly give in some detail the means by which you achieve a proportional band, reset and derivative action?

Marchment: Unlike the pneumatic equivalent, datum, set point or desired value is established by a predetermined current value which is used as a basis of comparison. Imagine therefore a simple movement with a double coil winding. One coil has a torque in one direction due to a current of 15 milliamps. representing say half level in a level controller. The other coil carries a current of 15 milliamps. representing set point or desired value and produces an equal and opposite torque. Balance is created under these conditions. Any deviation, (we will say for example that the current of the measured quantity rises to 16 milliamps. compared with 15 milliamps. set point current) causes the photoelectrical bridge to become unbalanced, the out-of-balance voltage being proportional to deviation. As the out-of-balance voltage is applied to the grid of the integral tube the plate current continues to change until the process restores the level to the equivalent of 15 milliamps.; the integral time being governed by the light intensity. Proportional band or throttling range is effected by shunting the 2 coils of the proportional unit, so causing a change in proportional current to require a larger or small output current to balance it. The control valve air pressure is proportional to the output current and a wide or narrow proportional band can be obtained by varying the sensitivity of the double coil unit. In the case of derivative or rate of change

action, the transmitter current flows through a resistor which has a voltage across it proportional to the measured quantity. The ends of the resistor are connected to a capacitor in series with a variable resistor. A voltage therefore appears across the variable resistor proportional to the rate of change of the measuring current. This voltage is applied to the grid of the integral tube and therefore causes a further movement of the valve.

Andersen: Do changes in photocell characteristics affect the rate?

Marchment: That is rather an important point and with the emissive type of photoelectric cell operating above a certain datum voltage, any variation in voltage applied to the cell does not influence the current output. It is only variation in light intensity that affects the rate of charging. It might be argued possibly that trouble might arise through variation of voltage on the integral tube but advantage is taken here of a very high negative feedback and it requires only a small change of current in that circuit to stabilize output and make it relatively independent of voltage variation.

Andersen: Would you like to comment on speed control relative to electrical machines?

Marchment: The reference made to the use of derivative was in the case of a power plant in which a compressor turbine was divorced from the power turbine. Speed control was the main requirement and the most valuable component for stability of control was found to be derivative.

Years of research have produced materials which can adequately resist corrosion and there are many choices these days. For the contacts in the transmitter we use platinum-iridium. Furthermore there is a resistor of the order of 0.75 megohm between the grid and the center contact, so contact resistance does not enter into the problem very much.

Bates: Would you discuss further the new approach to temperature measurement?

Marchment: I promise gentlemen that you will be among the first to receive details of the new approach to temperature measuremeat, but I do not think I am in a position at the moment to give any outline of that.

L. N. Combs (E. I. du Pont de Nemours & Co.): What accuracy of transmission can be expected from the electropneumatic system?

Marchment: The accuracy of the electropneumatic system is well within 1 percent.

Combs: Are there any special precautions necessary in transmision wiring? Can multi-conductor cable be used to transmit several variables in the same cable? Can transmission wires be placed in the conduits with power carrying wires? What type of wire can be used and at what voltage?

Marchment: As far as cables are concerned we can benefit very largely by the use of multi-conductor cables. The existence of external or associated conductors carrying alternating current will not in any way disturb transmission. The current is small, being a maximum of 30 milliamps., so the carrying capacity of the conductors is not so important as that they should be reasonably well insulated. The voltage impressed on the line is in the order of 60/70 volts. That brings up another point which is that the transmitter and connecting lines to the controller and those to the electropneumatic relay can be considered as intrinsically safe circuits. This is important, and I hope that some Government Manuals on the subject which I have distributed to members of the Recommended Practices Committee in this country, will be handed to the appropriate authority, and that instrument companies in America may benefit from them.

Andersen: Please go into detail on the square-root extractor of your flow meter.

Marchment: I mentioned that the torque exerted by the single pot coil, and the current were proportional to the differential head. If, however, the current passes through two fixed coils connected in series with a moving coil, the torque opposing that of the magnet float will be proportion-

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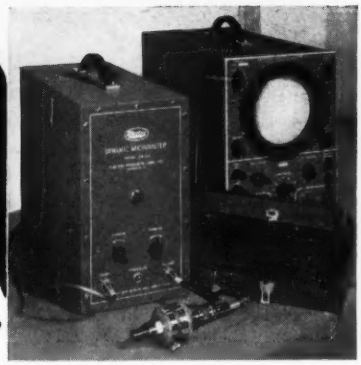

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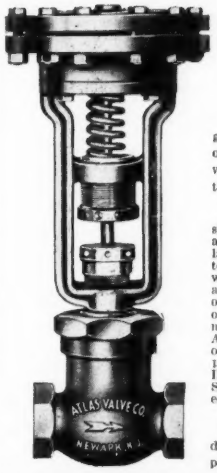

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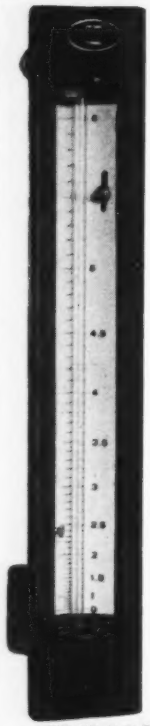

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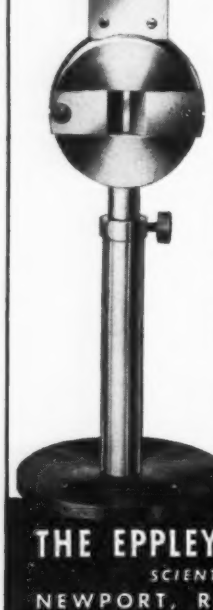

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*Vandaveer, Industrial & Engineering Chemistry, Vol. 22, page 596, June 1930.

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al to the square of the current and the current will be proportional to the flow. This arrangement is not new and forms the basis of many dynamometers.

J. R. Parsons (*Phillips Petroleum Co.*): Discuss in more detail the current bridge and the current-emissive photocell by means of which you derive the 50-minute time constant.

Marchment: The photocells being of the emissive type form a current bridge and it should not be regarded as an impedance bridge. Therefore the output from such a bridge may be used to slowly charge a capacitor, the charging law being linear. The capacitor value in this case is in the order of 24 microfarads. The integral or reset time is determined by the degree of brilliancy of the lamp. At set point the shutter is in a position to illuminate each cell with equal light intensity. Assuming deviation from a set point or desired value, integration will be at a rate proportional to deviation and in respect of time as governed by the brilliancy of the lamp.

R. Givens (*La Gloria Corp.*): Has this level indicator been worked on any closed type of pressure tank, such as tanks that hold butane and propane?

Marchment: The Precise tank gage is used for tanks which are non-pressurized. There is a slight leak due to passing a spindle through a flame trap hole which must be glandless to maintain sensitivity. There is another type of transmitter we have applied to Hortonspheres in which the specification called for a degree of accuracy less than that required for normal tank storage. Therefore we were able to use an instrument which enabled transmission of Hortonsphere levels to within 1 percent. In this case we use the electronic repeater transmitter the spring of which is wound up by a float-operated drum magnetically coupled to the shaft connected to the spring. The whole unit is in fabricated steel and arranged for mounting on a 10-in. ASA flange pipe.

INSTRUMENTATION of an Ammonia Plant

R. C. KING and PORTER HART, Dow Chemical Co.

(Published in *Instruments*, this issue, page 158)

Dr. B. W. Thomas (*Humble Oil and Refining Co.*): Will you elaborate on the gas analyzer shown in the last slide?

King: That is the gas analyzer on the recycle gas stream. This analyzer has a range of 60 to 80 percent hydrogen in air. Like all the other gas analyzers in the plant, it operates on the thermal conductivity principle. Since the thermal conductivity of hydrogen is 7 or 8 times that of air, this method is very dependable for analysis of hydrogen-air mixtures. As I mentioned in discussing the hydrogen collection system, the analyzers in that system have a range of 95 to 100 percent hydrogen in air. The controller analyzer which adjusts the ratio flow controller on the burner has a range of 65 to 85 percent hydrogen in order that 75 percent, where we want to operate, falls in the center of the scale.

H. M. Cook (*Celanese Corp.*): Will you elaborate on the physical characteristics of the reactors, physical dimensions, materials, and so on?

King: I purposely didn't go too deeply into that in the preparation of this paper, so I can't give you any actual engineering information on the construction of the reactor. It is constructed of steel, however.

R. E. Hansen (*Leeds & Northrup Company*): Why is the temperature of the reactor controlled by heaters in the reactor when the gas produces more than sufficient heat? Why not control the by-pass of the cold gas automatically?

King: The regulation of the temperature of the reactors is complicated by a number of factors. They are built in the open so that radiation losses vary widely, and rain showers change the temperature of the input gas sharply. On starting up the process, no gas is by-passed at all until the heaters have raised the temperature to the desired point. The adjustment of the power input to the heaters

is quite simple, rapid and positive, giving a very satisfactory uniform temperature in the reactor. This method of control eliminates the maintenance of a control valve of this size operating at high pressure, plus two additional block valves.

L. N. Combs (E. I. du Pont de Nemours & Co.): What is the life of Inconel-Alumel thermocouples in the hydrogen atmosphere at your operating temperatures?

Hart: We expect the life of this thermocouple to be at least 6 months.

M. K. Andersen (Carbide & Carbon Chemicals Corp.): What do you do in the hydrogen-producing plant to make it explosion proof? That refers to instruments, of course.

Hart: None of the instruments in the hydrogen-producing plant or the ammonia plant are explosion proof. The plants are built in the open, and hydrogen dissipates rapidly.

Andersen: Your process contains a multiplicity of safety and shut-down devices. How do you determine which one has been actuated by the trouble?

Hart: We have had that problem. Another relay system is being put in so that we can identify the one cause that may have shut down the plant.

Andersen: I know that your Company has been using colored panels and are also planning graphic panels. Will you make some comments on this subject?

Hart: The Dow Chemical Company, Texas Division, has been painting the control panels and instruments in light shades of harmonizing colors since early in the 1940s. It is our belief that it is most depressing for an operator to look at black panels and instruments all day. The colors definitely brighten up the control rooms. We think that colored panels and colored instruments have made better operators. Control rooms are kept cleaner; equipment is better cared for. This, we believe, definitely has a very good effect on operations throughout the plant. In fact, our plant is very highly colored throughout. In graphic panels, colors will be put to even a better use. Graphic panels will make operations less subject to mistake. I like to call this visual operation, and, as we are getting into very complex processes, a system of this type is quite necessary to keep the process before the operators. If anything can be done to lessen an operator's mistakes, it definitely should be done, and experience in industry today has proven that it will make an operator more productive, in that he can handle more processes.

Novak: I fully agree with the physiological aspect of color on the graphic. The point that I tried to make in my paper is the fact that this is not a decorative idea. It has actually been accused of being that. It serves a functional purpose and the addition of color is certainly a very desirable aspect but it is not the motivating aspect. This is not in disagreement with what Porter Hart had to say.

Andersen: Do you have any figures or approaches to figures giving the economic values of those panels? I understand the utility companies have actually made tests and can prove that they can get back on the line very much faster with a system that is self-explanatory, some sort of a graphic panel and they have published definite figures.

Hart: Are you talking about the cost of making a panel colored or are you talking about the economic value. I think that Ebasco is experienced in using graphic panels in power. They are doing it now very rapidly and believe in it so well that they have gone all out for such systems in their power plants and because then one man can handle the whole steam plant knowing what is happening in the one coordinated control room where everything is in front of him. It is such an experience as this that they tell about in the paper that a shut-down caused by something they did not know required something like 4½ hours to straighten out. The same thing repeated itself with their new type of panels, and bringing all controls together, along with their visual like operations, enabled them to come back on the line under the same conditions, in something like a matter of minutes—I think that it was 4½ minutes.

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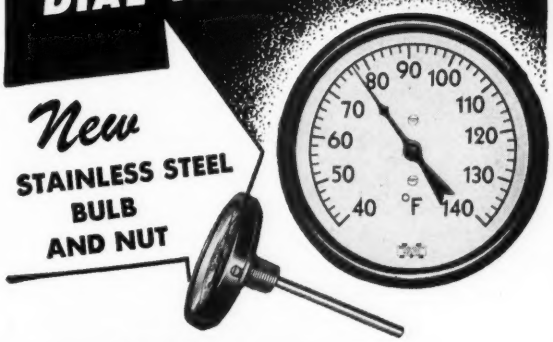

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 Continued from page 158

Reactors (Fig. 3)

The reactors, where the hydrogen and nitrogen are combined under high pressure and temperature in the presence of an iron catalyst, are temperature controlled. The reaction is exothermic, so the final temperature is held to the desired maximum by manually by-passing some of the inlet gas around the heat exchange in the outlet gas line. Actually, a slight excess of cold gas is by-passed and the temperature maintained by electric heaters in the reactors.

The temperature is controlled by a thermocouple instrument with a mechanical-electrical control system. The voltage output of this controller varies the grid potential on two Thyratron tubes supplying full-wave rectified d.c. to the core windings of a saturable core transformer. As the saturation of the core is varied, the output power to the heater is controlled. This method of heater control is used in other industries.

The exit gas, after passing through heat exchangers countercurrent to the inlet gas, is refrigerated in condensers with anhydrous liquid ammonia. The temperature is controlled by a back-pressure regulator in the ammonia vapor line.

The liquid anhydrous ammonia condensed from the process goes into a separator from where it is forwarded to the storage tanks. This product flow is measured with an orifice flow transmitter (mercuryless type) and recording receiver.

After the liquid ammonia has been separated, the process gas is recompressed and recycled to the inlet of the reactor. The speed of the recycle compressor is controlled from the suction pressure with the same type of control system as that used on the other compressors.

Refrigeration

Large quantities of cooling water are used throughout the plant. The condensers which remove the product ammonia from the gas stream are cooled by liquid ammonia. This ammonia vapor as well as that from the storage tanks and vents, is recovered by mechanical refrigeration systems where the vapor is compressed, cooled, and the liquid ammonia returned to storage. There is also a large absorption refrigeration plant using a gas-fired reboiler on the rectifier column.

Conclusion

The air for all control instruments and cylinder-operated safety shut-off valves is dried to zero degrees Fahrenheit dew point at 100 psi. pressure in a silica gel drier. The control and transmitter air lines are quarter-inch galvanized pipe. Transmitters and receivers are used entirely in the recording and controlling of pressures, flows, levels, and other variables. All of the flow transmitters measuring ammonia and most of the other flows in the plant are the mercuryless type. This prevents any possible reaction between mercury and ammonia. All thermocouple, resistance thermometer, and gas analyzed instruments are of the electronic balancing type which eliminates the effect of vibration pick-up from the compressor system.

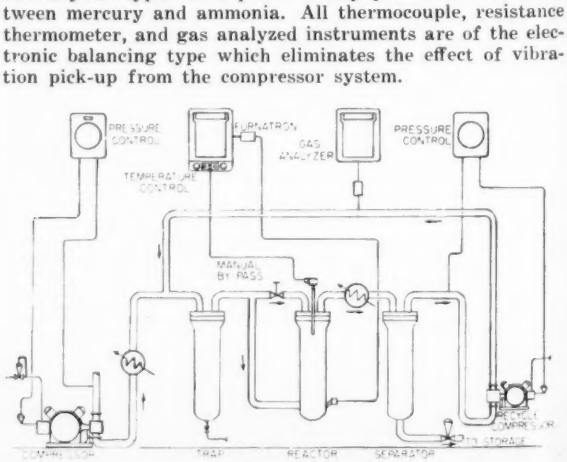
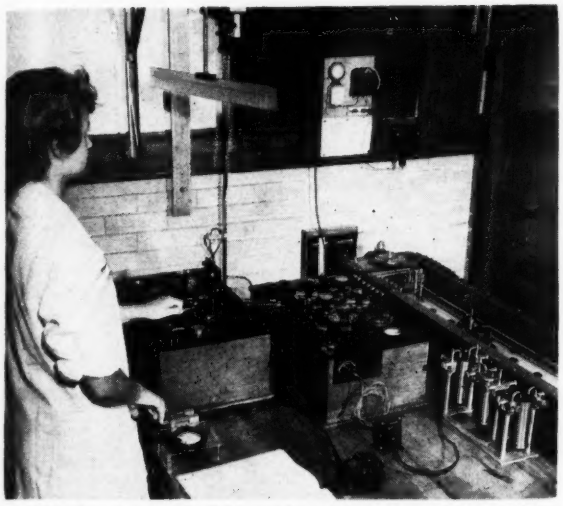


Fig. 3. Reaction System

There are no specially-developed instruments used for controlling any part of this ammonia plant. Some of the control problems are complicated by the high presusres, but the basic instruments are not changed. It is felt that some of the automatic process control systems have improved a few operations that in older plants were performed manually. As operating experience is gained with this plant, it is possible that still further applications for automatic process controls may become apparent. Certainly, no instrument engineer ever complacently considers that all that can be done has been done, even with a 35- or 40-year old process.

January Cover Correction



Calibration of a Mueller Bridge at the National Bureau of Standards.

The above picture, with the caption as it appeared on our January cover make up the correct combination as it should have appeared last month. The illustration which did appear was incorrectly designated by the National Bureau of Standards as Fig. 6 of the article appearing on page 35 of our January issue.

The following is quoted from a letter from William K. Gautier of the Bureau's Technical Report Section:

"The cover picture of the January issue of *Instruments* first brought to my attention an error on our part. In some way the wrong photograph was sent out as Fig. 6 for use with Technical Report 1489, 'Standards for Electrical Measurements,' by Francis B. Silsbee . . . Our only consolation in this matter is that the mistake was made in the Bureau's photographic laboratory, rather than in this office . . ."

The instrument assembly pictured on the January cover is a Knorr-Albers recording microphotometer comprising a Leeds & Northrup scanning unit in the foreground and the associated L & N "Speedomax" instrument in the rear.

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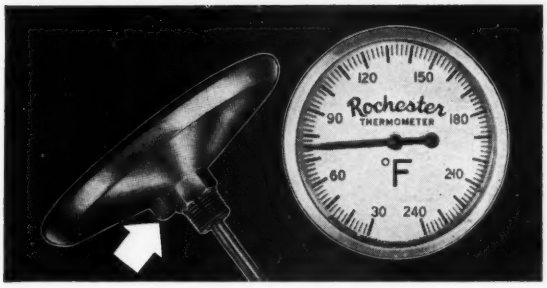

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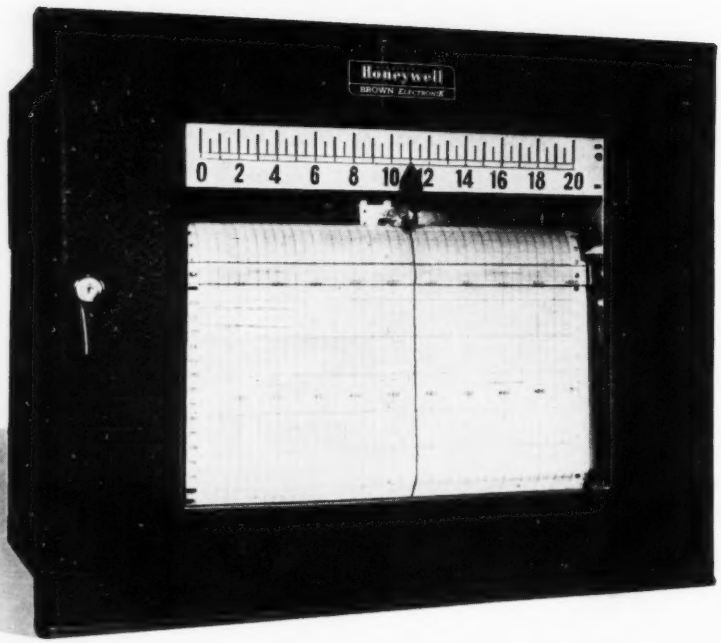

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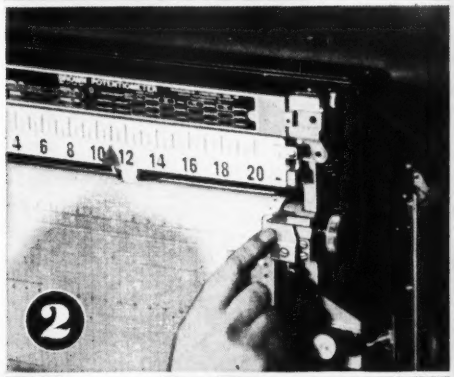

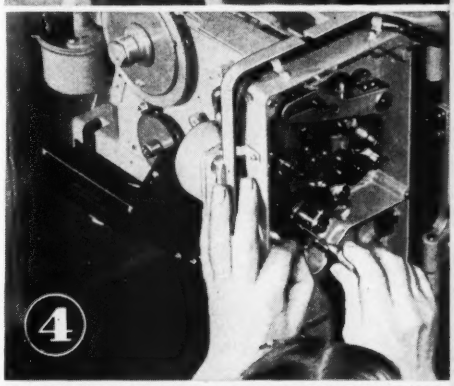

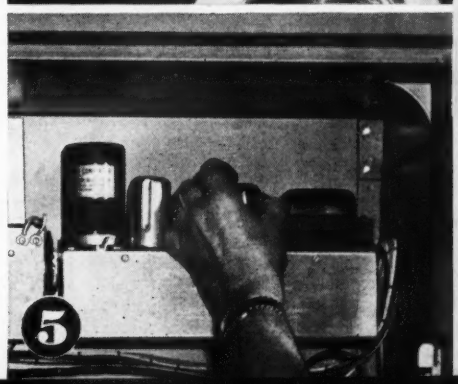

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Millivoltmeter Pyrometers

New line of millivoltmeter pyrometer indicators and controllers has 7-in. scale. Indicators are accurate to 0.75 percent; movement has 3.25-lb. Alnico

magnet. Controllers use plug-in units; are sensitive within 0.1 percent; are available for two- or three-position action with thermocouple-break protection standard. Over-temperature protector model requires manual reset to restart process.—*Meter and Instrument Divs., General Electric Co., Schenectady 5, N. Y.*

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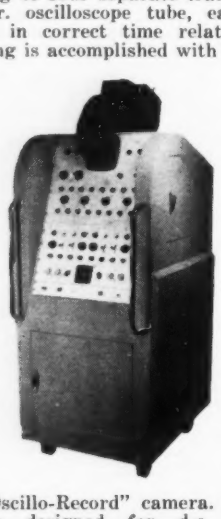
Vibration and Strain Analyzer

New "H-42A Strainalyzer" makes possible simultaneous observation and recording of four separate traces on a 5-in. c-r. oscilloscope tube, each appearing in correct time relationship. Recording is accomplished with a Fair-

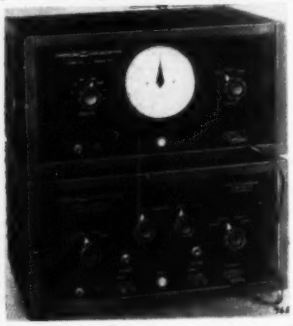


child "Oscillo-Record" camera. Instrument is designed for d-c. bridge excitation from self-contained batteries and has high-gain amplifiers, balance controls and voltage and calibration controls for each strain gage bridge channel. Durations of linear sweep generators have been extended to 10 sec. for study of low-frequency phenomena. Unit is not acoustically sensitive.—*Electronic Tube Corp., 1200 E. Mermaid Lane, Philadelphia 18, Penna.*

Mention No. 202 when filling out card.

High-speed Chronoscope and Input Adapter

New "Model 110" high-speed chronoscope has 8 ranges from 1 millisec. to 3 sec. Instrument indicates on time scale percentage of charge lost by capacitor connected across resistor. Accuracy is 1 percent of full scale on any range. Unit operates on open or short



circuit or a pulse 6 v. or more. New "Model 211" input adapter separates start and stop operation of chronoscope. Either signal can be chosen as a pulse of at least 1 v., an open or short circuit. Features include sensitivity control for magnitude of signal, lock-out to reject stop before start signal, and acceptance of only first time interval presented. Both units operate from 110 v. 60-cps. line—*American Chronoscope Corp., 316 W. First St., Mt. Vernon, N. Y.*

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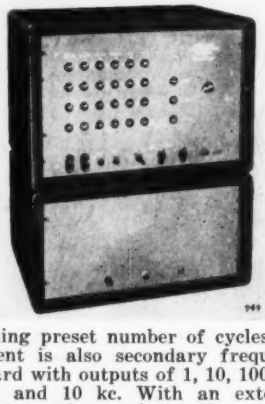
RF Timer and Counter

New "Model 801" frequency-time counter measures frequency to 1 Mc. with an accuracy of 0.001 percent by either counting cycles in 1-sec. intervals



or timing preset number of cycles. Instrument is also secondary frequency standard with outputs of 1, 10, 100 cps. and 1 and 10 kc. With an external generator unit can be used as a tachometer.—*Potter Instrument Co., 115 Cutter Mill Road, Great Neck, N. Y.*

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Rotor Temperature Recorder

New special model of maker's electronic recorder measures temperature of rotor in large electric generators. Instrument range is 0 to 150 C.; has limit error of 1.5 deg. C. and pen speed of 1.4 min. full scale. Range of rotor winding resistance is 0.1 to 4.0 ohms; unit has dielectric test of 1,500 v. rms. for 1 minute.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia 44, Pa.*

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Pneumatic Dimension Gage

New "Dimensionair" gage has range of 0.003 in. with amplification of 2500:1. Gage plug connections made without wrenches; chrome-plated plugs have

large jets and deep recess clearance and can be inserted with jets at any angle. Supply air pressure from 40 to 100 psi. Indicator has jeweled bearings. —*Federal Products Corp., 1144 Eddy St., Providence 1, R. I.*

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Barrel Filling Meter

New 60-gpm. barrel filling meter measures repeat quantities from 25 to 79 gal. by 1-gal. increments. Different quantity settings are obtained by changing one gear. A totalizing counter registers total through-put; a reset counter indicates number of containers filled. Meter control valve has variable deceleration in shut-off speed to pre-

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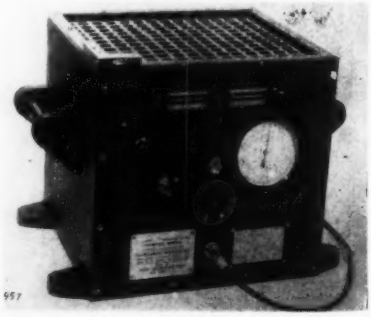
Magnetic-coupling Dynamometer

New "Model 11A" dynamometer measures torque developed by prime movers from 0.5 to 10 hp. and is calibrated from 1500 to 6000 rpm. Torque is obtained by referring dial reading to



chart; speed is given directly. Instrument consists of 2 concentric cylinders coupled by a variable magnetic field through iron particles. Inner member is restrained by calibrated springs whose movement provides indication of applied torque. Over-all dimensions 11 x 11 x 12 in.; weight 130 lbs.—*Avion Instrument Corp.*, 121 *E. 24th St., New York* 10, *N. Y.*

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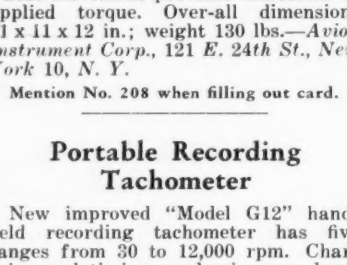
Portable Recording Tachometer

New improved "Model G12" handheld recording tachometer has five ranges from 30 to 12,000 rpm. Chart drive and timing mechanism are hand



wound; paper speeds are 0.25 and 0.5 in. per sec. Chart is 2.75 in. wide. Rubber-tired wheel is used to read fpm. Accuracy is 0.5 percent at any reading.—*O. Zernickow Co.*, 15 *Park Row, New York* 7, *N. Y.*

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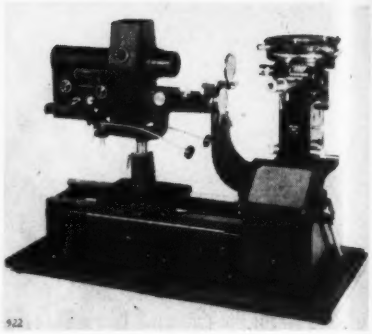
Metallographic Microscope

New "Model MeF Reichert" metallurgical microscope has a built-in camera and magnification from 4.5 to 2200×. Ordinary or polarized light can provide bright- or dark-ground illumination, with instantaneous changeover. Specimen is automatically aligned perpendicular to optical axis; it can be observed in eyepiece until photograph is taken. Accessories available include micro-hardness tester, and means for projection and drawing.—*Wm. J. Hacker & Co.*, 82 *Beaver St., New York* 5, *N. Y.*



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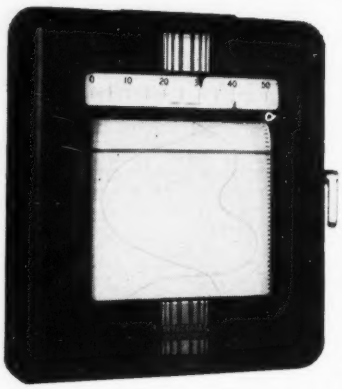
Two-pen Recorder

New "Speedomax" recorder houses two instrument systems in one case; pens operate overlapped or side-by-side.



Any of maker's usual primary elements can be used; full-scale pen travel can be 1, 2, or 3 sec. One record is in black second in red.—*Leeds & Northrup Co.*, 4934 *Stenton Ave., Philadelphia* 44, *Pa.*

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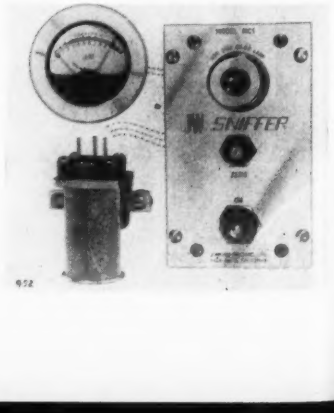
Combustible Gas Indicator

New "Sniffer" combustible gas indicator for marine applications consists of detector, control box and indicator. Detector mounts in space to be monitored; has heavy monel metal screen. Water-proof control box has interlocks



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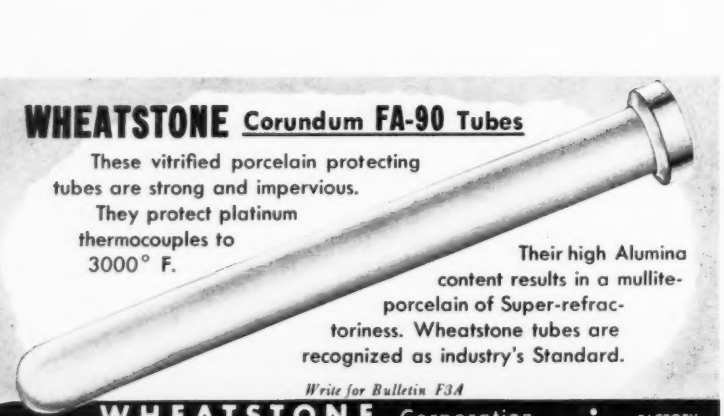

Write for Bulletin F3A

WHEATSTONE Corporation
2436 Reading Road Cincinnati 2, Ohio
FACTORY FOSTER, KY.

so engine cannot start until instrument is activated. Indicator is hermetically sealed for flush mounting.—*Johnson-Williams, Ltd.*, 2613 *Third St., Palo Alto, Calif.*

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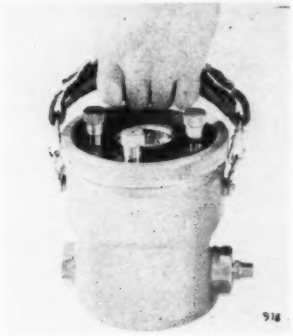
Combustible Gas Indicator

New "Type EP-200" explosion-resistant combustible gas indicator for Class I, Group D atmospheres operates on Wheatstone bridge circuit with plati-

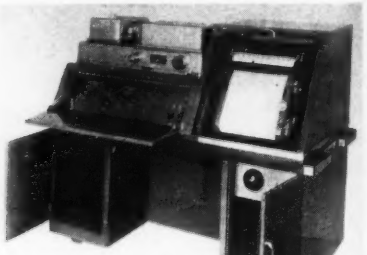


num measuring elements. Neoprene suction hose with plastic probe is used. Over-all dimensions 3.5 in. diam. by 6.5 in. high; weight 6 lbs.—*Lor-Ann Instrument Co.*, 58 *Montgomery St., Jersey City* 2, *N. J.*

Mention No. 213 when filling out card.

Mobile Infrared Spectrometer

New "Model 12-C" infrared spectrometer cabinet is caster-mounted; unit measures 54 x 46 x 30 in. and requires only water and electricity for operation. A protective door over controls folds down to form workshelf; storage space



is provided below for accessories. Reduced recording time of a complete spectrum is obtained by automatic speed change programming on new wavelength drive. Densitometer attachment reads directly in absorbance or transmittance. Two-second L & N "Speedomax G" recorder included as standard equipment.—*Perkin-Elmer Corp., Norwalk, Conn.*

Mention No. 214 when filling out card.

Wide-band Sweep Marker

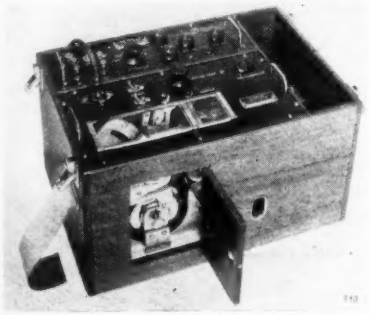
New "Rada-Sweep" marker produces constant-amplitude FM signal for determining frequency response of radar IF amplifiers. Center frequency of

sweep may be switched to 30 or 60 Mc.; wide-band sweep width is 20 Mc.; narrow-band width is 3Mc. Instrument has pulse-type crystal-positioned markers at 25, 35, 55 and 65 Mc.; each marker is switch controlled. Output is up to 0.5 v. into 70 ohms; AM while sweeping is less than 0.1 db per Mc.—*Kay Electric Co., 14 Maple Ave., Pine Brook, N. J.*

Mention No. 215 when filling out card.

High-speed Inkless Strain Recorder

New "Baldwin-Sanborn" recorder is a direct-writing inkless VTVM consisting of a modulated-carrier type a-c. strain-gage amplifier, a D'Arsonval moving-coil recording galvanometer, and a paper drive mechanism. Bridge output is amplified at 2500 cps. rectified by a phase-sensitive detector circuit. Resulting d.c. is applied to a driver amplifier that operates recorder.

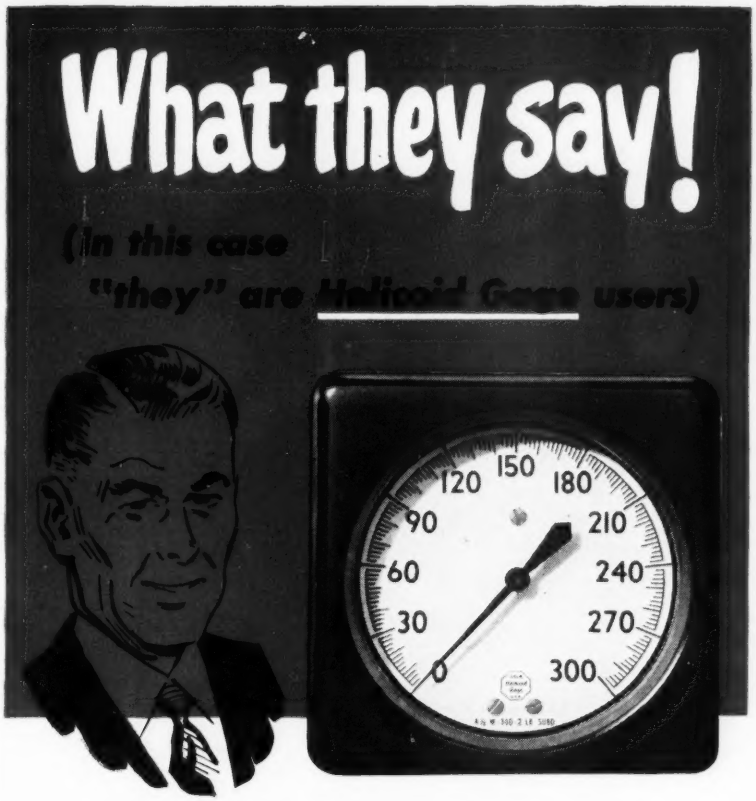


Input impedance of carrier amplifier is 2000 ohms and a 100-microvolt 2500-cps. signal applied to input produces deflection of 1 cm. at recorder or 30 v. if entire system is terminated in its proper load. Response time for square-wave input is approximately 0.007 sec. At recording levels of 10 mm. peak-to-peak, frequency response is flat from zero to 40 cps. Controls are provided for adjusting resistive and capacitive balance of bridge. Writing arm has heated stylus which wipes across heat-sensitive record paper producing a black line on white background. Standard paper speed is 25 mm. per sec. Over-all dimensions 17 x 11.75 x 9.5 in.; weight 32.5 lb.—*Testing Equipment Dep't., Baldwin Locomotive Works, Philadelphia 42, Penna.*

Mention No. 216 when filling out card.

Dynamic Condenser Electrometer

New "Model 361-20" electrometer has switch-selected ranges of 0 to 10, 100, 1000, mv. d.c. Standard input resistances up to 100,000 megohms are pro-



"We use your Helicoid Gages in very severe pulsation work and have found them very satisfactory."

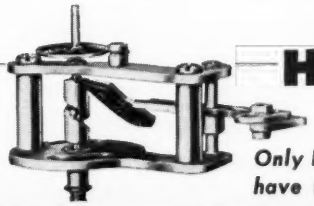
"A Helicoid Gage operating under the worst conditions for 4,000 hours is still functioning, although other gages have been worn out."

". . . no other gage has come close to giving such long life and accuracy as the Helicoid."

"Your Helicoid Gages have been used in our plant for more than five years and have proved their superiority over competitive makes."

"We have six gas engines equipped with Helicoid Gages on the oiling system, subject to more vibration than any rack and pinion gage will stand."

All quotes are taken from letters in our files. Write today for HELICOID GAGE catalog.



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Only Helicoid Pressure Gages have the Helicoid Movement

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TOOLMAKER MICROSCOPE
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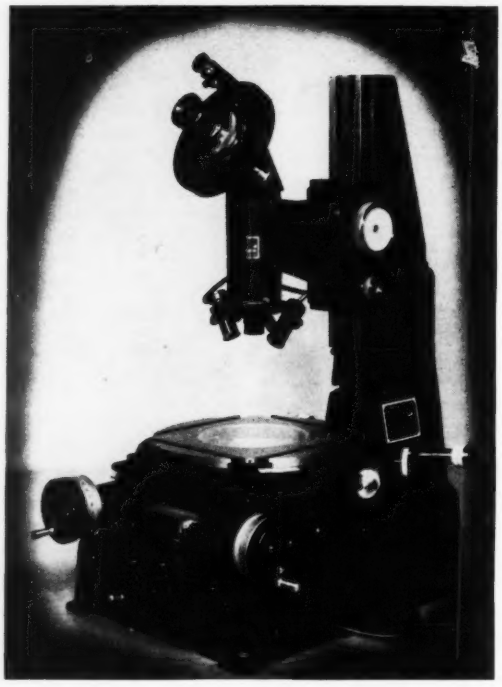

Especially useful for checking gear tooth spacings, laying out cam contours, and in performing numerous other precision measurements in either rectangular or polar coordinates.

Stage Rotation	360°
Direct reading to	1 minute
Coordinate Range	4 x 2 inches
Direct reading to	0.0001 inch

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A NEW AIR METER
FOR HIGH-ACCURACY AIR VELOCITY MEASUREMENTS

Read directly from the palm of your hand, Hastings Air Meter registers ranges from 5 to 6,000 fpm . . . weighs only 24 ounces. Powered by 110 volt or portable supply.
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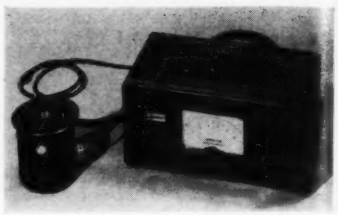
P.O. BOX 1275 HAMPTON, VIRGINIA



vided for micro-current measurements. Indicator pointer travels full scale in 1 sec. Dynamic condenser converts input to proportional a-c. signal which is amplified, converted to d.c., and shown on indicator. High impedance surfaces are gold plated; polarity and range switch make possible use of conventional recorders. Amplifier case size is 7 x 17 x 10 in.; operates from 115 v., 60 cps.—*Loudon Instruments, Inc.*, 5644 *Lake Park Ave., Chicago* 37, *Ill.*

Mention No. 217 when filling out card.

Portable Multi-range Indicator

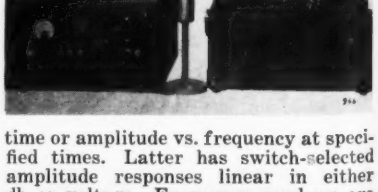
New "Model 666-RL" indicator reads alternating and direct voltage from 0 to 5000 at 1000 ohm per v. d.c. to 10

amp. and resistance to 3 megohms in four ranges. 3-in. indicator used has black and red markings on a white background. Selector switch is molded plastic.—*Triplett Electrical Instrument Co., Bluffton, Ohio.*

Mention No. 218 when filling out card.

Vibration and Noise Analyzer

New "Vibralyzer" provides Fourier analysis of signals from 5 to 4400 cps. by direct-writing process. Instrument records amplitude vs. frequency vs.

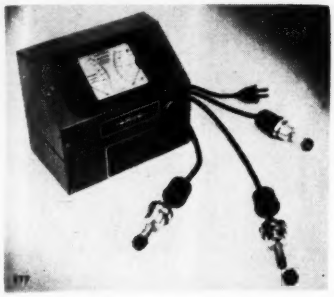


time or amplitude vs. frequency at specified times. Latter has switch-selected amplitude responses linear in either db or voltage. Frequency markers are available for calibration of records. Unit operates on 115 v. 60-cps. line.—*Kay Electric Co., Pine Brook, N. J.*

Mention No. 219 when filling out card.

Thermocouple Vacuum Gage

New thermocouple vacuum gage is calibrated 0 to 1000 microns Hg. Nickel-plated gage element containing noble-metal thermopile has 0.125 in. pipe

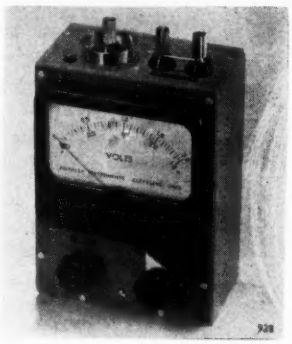


thread. Switching attachment connects five primary elements to indicator; length of connecting cable does not affect calibration.—*Hastings Instrument Co., Super Highway at Pine Ave., Hampton, Va.*

Mention No. 220 when filling out card.

Vacuum-tube Electrometer

New "Model 200" electrometer has ranges of 2 and 20 v. d.c.; accuracy is 2 percent of full scale. Input impedance



is over a billion megohms shunted by 6 uuf. A 1-megohm series input resistor protects electrometer tube from overvoltage.—*Keithley Instruments,* 1507 *Warrensville Center Rd., Cleveland* 21, *Ohio.*

Mention No. 221 when filling out card.

Electronic Temperature Regulator

New electronic temperature regulator is used in aircraft cabin application. Instrument combines signals from mixing duct, cabin, and outside air to control valve in warm-air by-pass. Signals from duct and outside air are proportional to rate of temperature change. Over-all size of regulator 6.25 x 5 x 4.75 in., weight 4.5 lbs.—*AiResearch Mfg. Co., Div. of Garrett Corp.,* 9851-9951 *Sepulveda Blvd., Los Angeles* 45, *Calif.*

Mention No. 222 when filling out card.

D-c. Power Supply

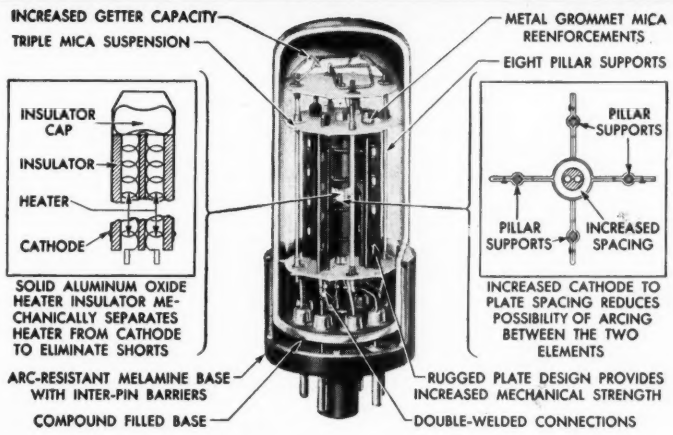
New high-voltage unit is filtered 4500-v. r-f. d-c. power supply com-

RECTIFIER TUBES

RUGGEDIZED BY

ECLIPSE-PIONEER

FOR ADDED RELIABILITY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CATHODE
SOLID ALUMINUM OXIDE HEATER INSULATOR MECHANICALLY SEPARATES HEATER FROM CATHODE TO ELIMINATE SHORTS
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INCREASED CATHODE TO PLATE SPACING REDUCES POSSIBILITY OF ARCING BETWEEN THE TWO ELEMENTS
ARC-RESISTANT MELAMINE BASE WITH INTER-PIN BARRIERS
COMPOUND FILLED BASE
RUGGED PLATE DESIGN PROVIDES INCREASED MECHANICAL STRENGTH
DOUBLE-WELDED CONNECTIONS

We are not in the standard vacuum tube business, but we are in the business of developing and manufacturing a reliable line of special purpose electron tubes—tubes that will serve and meet the stiff and varied operational requirements of aviation, ordnance, marine and other fields of modern industry. Typical of these are receiving type tubes such as Beam-Power Amplifiers, R-F Pentodes, Twin Triodes, and the Full-Wave Rectifiers illustrated above and described below. All of these tubes are exhausted on a special automatic exhausting machine capable of extra high evacuation, and are aged under full operating and vibration conditions for a period of 50 hours. In addition to the tubes described above, Eclipse-Pioneer also manufactures special purpose tubes in the following categories: gas-filled control tubes, Klystron tubes, spark gaps, temperature tubes and voltage regulator tubes.

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REG. U. S. PAT. OFF.

Electrical Characteristics of E-P Full-Wave Rectifier Tubes

TUBE TYPE	R.M.A. 5838	R.M.A. 5839	R.M.A. 5852	R.M.A. 5993
Heater Voltage	12 volts	26.5 volts	6.3 volts	6.3 volts
Heater Current	0.6 amps.	0.285 amps.	1.2 amps.	0.80 amps.
Peak Inverse Voltage	1375 v. (max.)	1375 v. (max.)	1375 v. (max.)	1250 v. (max.)
Peak Plate Current (per plate)	270 ma. (max.)	270 ma. (max.)	270 ma. (max.)	230 ma. (max.)
D-C Heater-Cathode Potential	450 v. (max.)	450 v. (max.)	450 v. (max.)	400 v. (max.)
Cathode Heating Time	1 min.	1 min.	1 min.	45 sec.
Total Effective Plate Supply Impedance	150 ohms (min.)	150 ohms (min.)	150 ohms (min.)	150 ohms (min.)

Other E-P precision components for servo mechanism and computing equipment:

Synchros • Servo motors and systems • rate generators • gyros • stabilization equipment • turbine power supplies and remote indicating-transmitting systems.

For detailed information, write to Dept. A

ECLIPSE-PIONEER DIVISION of Bendix AVIATION CORPORATION

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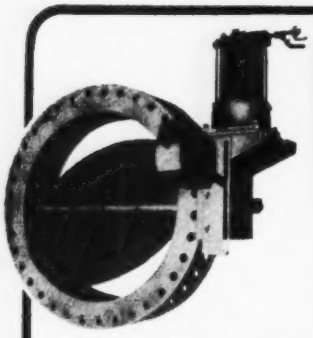
Export Sales: Bendix International Division, 72 Fifth Avenue, New York 11, N. Y.



42" butterfly valve with oil-operated cylinder and counterweight for 200°F service.

30" butterfly valve for 60 p.s.i. pressure, with Limitorque motor control and auxiliary handwheel, position indicating lights and push button.

ROCKWELL AUTOMATIC BUTTERFLY VALVES

Provide Automatic Flow Control and Quick Shut-Off of Air, Gases, Steam, Liquids, Semi-Solids.

A complete line of Rockwell Valves of any metal or rubber-lined; in pipe size to 72" and larger; with any type of automatic control and with auxiliary manual control, if desired.

We also manufacture manually controlled butterfly valves and slide valves in all sizes, metals and types for pressures to 100 p.s.i.

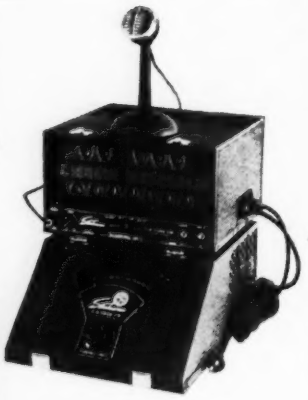
Write for Valve Catalog and ask to be put on our mailing list to receive "Rockwell Valvings" monthly.

W. S. ROCKWELL CO.

264 Eliot St. Fairfield, Conn.

THE NEW 6T-4 Stroboconn

PRECISION STROBOSCOPIC FREQUENCY METER



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Measures transient vibrations. Finds precise speed of rotating mechanical parts. Calibrates or checks precision tachometers, oscillators, other pulse generators. Used in place of bridge methods in measuring inductance and capacitance. Many other uses.

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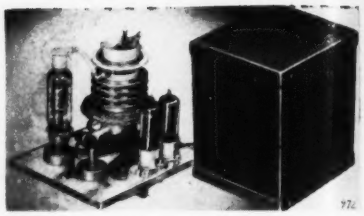


pletely enclosed, measures 5.6 x 4.5 x 5 in. Voltages to 7500 v. at 1 ma. obtainable.—*Spellman Television Corp.*, 3029 *Webster Ave., New York* 67, *N. Y.*

Mention No. 223 when filling out card.

Metal-enclosed D-c. Power Supplies

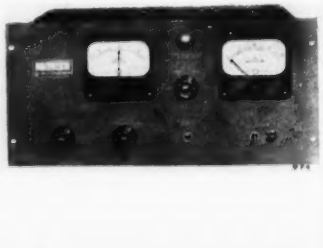
New line of metal-enclosed d-c. power supplies utilizing selenium rectifier stacks can be furnished to supply 125 or 250 v. d.c. from a 208-, 230-, or 460-

v. three-phase, 60 cps. supply. Convection-cooled units available in ratings to 5 kw.; fan-cooled are rated to 25 kw. Equipment has built-in contactors with thermal overload protection and fused disconnect switches.—*Lighting & Rectifier Div., General Electric Co., Schenectady* 5, *N. Y.*

Mention No. 224 when filling out card.

FM Communications Monitor

New "Model 337A-B" FM communications monitor uses same pulse-counter circuits employed in maker's monitors for commercial broadcasters. Instrument gives continuous indication of frequency and modulation swing and monitors by transmitter output sampling or antenna pickup. It includes



peak-modulation indicator and audio out-put for aural monitoring; frequencies from 30 to 175 Mc. may be monitored. "Model 337A" operates on one crystal-controlled frequency and "Model 337B" operates on any of four frequencies.—*Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, Calif.*

Mention No. 225 when filling out card.

A-f. Wattmeter

New "Model OP-962" a-f. wattmeter covers range from 0.1 milliwatt to 100 watts. Instrument has 40 switch-selected impedances from 2.5 to 20,000

ohms with 2 percent accuracy from 30 cps. to 10 kc. Binding posts are provided for input, external amplifier, and CRO. Over-all size 15.25 x 8.5 x 8.5 in.; weight 20.5 lbs.—*Daven Co., 191 Central Ave., Newark 4, N. J.*

Mention No. 226 when filling out card.

Linear Amplifier for Proportional Counting

New "Model 1061" linear amplifier is connected between detector and scaler; provides sensitivity adjustment calibrated in mv. with choice of 1 or

10 mv. max. Instrument has flat frequency response from 10 kc. to 1.5 Mc. Oscilloscope terminals are located on front panel; scaler may operate independently without disconnecting from amplifier.—*Nuclear Instrument & Chemical Corp., 223 W. Erie St., Chicago 10, Ill.*

Mention No. 227 when filling out card.

Microvolt Signal Generator

New "Model 292X" signal generator has seven ranges from 125 kc. to 220 Mc. Instrument provides controlled output from 0.2 microvolt to 0.1 v. through a 10:1 attenuator. It may also

T-70X Timer Thermostat No. 48—Product of General Controls Company Glendale, California

Was *your* house cold this morning? Nearly everyone lowers the thermostat at night, both for fuel economy and more comfortable sleep—but why get up in the cold, re-set the thermostat, then wait for higher temperatures to chase away the chills?

Sleep in every morning . . . let Chace Thermostatic Bimetal chase night-time chill . . . and get up in a warm, comfortable house! Chace Bimetal actuates this General Controls Timer Thermostat, which lets you do just that. Set one dial for desired day-time temperature, the other lower, for night. Then set the timer at bedtime like an alarm clock; the control takes over, maintains economical lower temperature all night . . . gives you a "warm reception" in the morning.

The dependable response of Chace Thermostatic Bimetal means satisfied users for this thermostat—*and for your product, too!* Chace Bimetal is furnished in strips, coils, fabricated elements or sub-assemblies. We offer complete engineering, laboratory and production facilities and the counsel of Chace Application Engineers. Take advantage of these services when you have problems involving temperature-responsive devices.

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Measure Time Intervals

From 10 Microseconds to 3 Seconds

The time interval between any two components in electrical, mechanical or electro-mechanical systems can *now* be measured, *simply* and *accurately*, with American Chronoscope Equipment.

The Model 211 Input Adapter used in conjunction with the Model 110 American Chronoscope separates the functions of STARTING and STOPPING the measurement of time. Simply connect the Start and Stop leads from the adapter to any two components of a system under test. Only the first complete elapsed time interval presented is accepted. This reading is indicated on the Chronoscope and remains fixed until reset.

PRICES
Model 110 Chronoscope $475
Model 211 Input Adapter . . . $265

For complete description on these and other Chronoscopes and Adapters, write for Bulletin 2008

American Chronoscope
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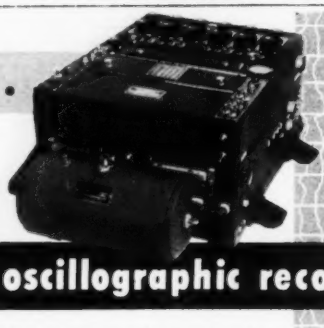
All you need . . .



for complete oscillographic recording

The S-8 Oscillograph, long the standard of oscillographic recording, has been improved to meet the expanding demands of modern research. The NEW Type S-8 Oscillograph has *all* the inherent capabilities you need to record rapidly changing phenomena such as vibration and dynamic strain.

A few of the newest features are:

QUICK-CHANGE TRANSMISSION—16 record speeds over range of 120:1

FULL RESILIENT MOUNTING makes possible use of super-sensitive galvanometers

CHART TRAVEL INDICATOR provides continuous indication of chart motion

NEW GALVANOMETER STAGE takes all Hathaway galvanometers for recording milliamperes, microamperes, and watts.

NEW RECORD-LENGTH CONTROL and NUMBERING SYSTEM for long, trouble-free service

All the other valuable features characteristic of the S-8 are retained. Investigate the NEW Type S-8 and its 170 types of galvanometers.

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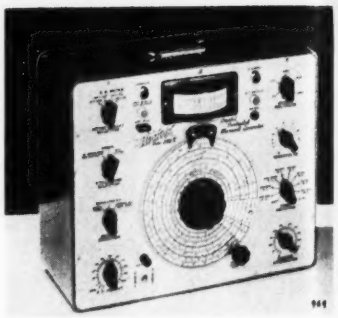


be externally modulated from 15 cps. to 10 kc. AF output is 0 to 2 v. at 400 cps. Features include temperature compensation, excellent frequency regulation with output, and minimum leakage.—*Hickock Electrical Instrument Co.*, 10519 *Dupont Ave., Cleveland* 8.

Mention No. 228 when filling out card.

Calibrated Voltage-dividing Rheostat

New "Selectohm" is a linear v-d.r. calibrated 0 to 100,000 ohm; rated at 25 watts.—*Chicago Industrial Instrument Co., 536 W. Elm St., Chicago* 10.

Mention No. 229 when filling out card.

Replaceable Power Resistor

New type "H30N Greenohm" resistor has insulated safety knob and Edison

screw base. Unit is available in wide range of wattages and resistances.—*Clarostat Mfg. Co., Inc., Dover, N. H.*

Mention No. 230 when filling out card.

Molded Terminals

New "Series 1400" insulated miniature terminal lugs stand-offs and feedthroughs are molded with either melamine or phenolic to JAN P14 specifications. Molded construction said to eliminate internal air gaps which act as moisture traps.—*U. S. Engineering Co.*, 521 *Commercial St., Glendale* 3, *Calif.*

Mention No. 231 when filling out card.

High-voltage Selenium Rectifier Cartridge

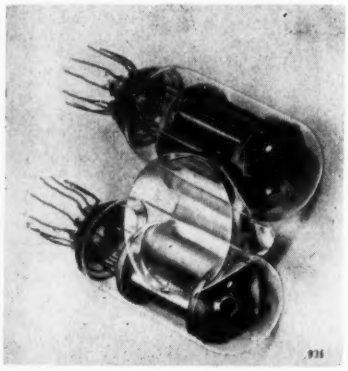
New line of selenium rectifiers has ratings up to 25 kv. per cartridge with currents up to 75 ma. Sizes range from

0.125 to 1 in. diameter; units operate from −55 to 100 C. Cartridges available in phenolic tubing or hermetically-sealed metal assemblies with pigtail leads.—*International Rectifier Corp.*, 6809 *S. Victoria Ave., Los Angeles* 43, *Calif.*

Mention No. 232 when filling out card.

Crystalline and Plastic Phosphors

New crystalline and plastic phosphors are designed for use in scintillation detectors. Crystals of "Stilbene" up to 1 in. in any dimension are readily



machined; material is non-volatile humidity-stable and gives uniform response. New luminescent plastic (illustrated) can be molded larger than 1 in. into many shapes. Pulses from plastic are weaker than from "Stilbene" but both have same pulse duration.—*Tracerlab Inc.*, 130 *High St., Boston* 10, *Mass.*

Mention No. 233 when filling out card.

Miniature High-range Detector, Charger & Reader

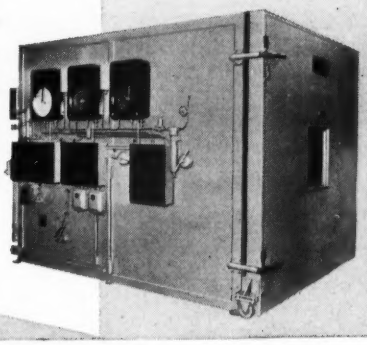
New "Model L-50" chamber is 0.5 in. diameter, 1.56 in. long; unit is hermetically sealed with a flexible diaphragm for charging. Range is 0 to 100 roentgen with total exposure of

DON'T LET U.S.A.F.

No. 41065-B

GET YOU DOWN, BILL... TAKE IT TO TENNEY

This Tenney Variable Temperature—Humidity Chamber was built to run high temperature, humidity, and mildew-resistance tests (Groups 10, 30 & 70) on aircraft electronic equipment and components under 41065-B. Specified range from 60° F. to 200° F. Relative humidity 20% to 95%. Sizes from 3 cu. ft. to walk-in rooms.



"Take it to Tenney" is sound advice when you're faced with a testing problem. For years Tenney has specialized in designing and building testing equipment to meet the strictest specifications for sand and dust, low temperature, high altitude, liquid immersion, salt spray and many other conditions. Absolutely accurate simulation of changing conditions can be obtained through the use of Tenney program control apparatus. Tenney engineers are always available for consultation and help. You need only ask for their assistance. ***For literature and further information write Tenney Engineering, Inc., Dept. B, 26 Avenue B, Newark 5, New Jersey.***

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Series "E" HYCOR Precision Resistors are designed for use in applications requiring accuracy, stability and long life under conditions of extreme temperature variation plus moderately high humidity. For a slight additional cost they are supplied "tropicalized" against extreme humidity and fungus growths. All types are noninductively wound on nonhygroscopic bobbins with resistance wire having the lowest temperature coefficient available.

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10,000 r. New "Model L-40" charger and reader is used with "L-50" chamber; all parts are mounted with interconnected sockets in solid conducting plastic chassis. Unit has no batteries, wires or soldered joints; one turn of knob gives full charge.—*Landsverk Electrometer Co., Pippin Road, Cincinnati 31, Ohio.*

Mention No. 234 when filling out card.

Radioactivity Detector for Workers' Hands and Feet

New "Hand and Foot Checker" measures extent of beta and gamma contamination on hands and feet of those engaged in handling radioactive materials. Subject steps on foot platform and puts hands in hand pockets. G-M tubes transmit pulses through scalers to electromechanical registers proportional to number of beta-gamma rays striking each tube. Five registers provide a count of palm and back of each hand, as well as feet.—*Special Devices Div., Austin Co., 19 Rector St., New York 6, N. Y.*

Mention No. 235 when filling out card.

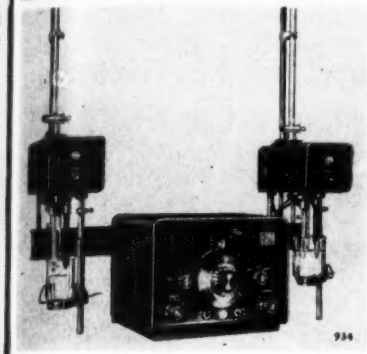
Low-range Dosimeter with Electrostatic Charger

New low-range dosimeter clips into pocket; integrated exposure to gamma- and x-rays from 0 to 200 milliroentgen is read directly from microscope reticle. Unit is all plastic except quartz fiber and is hermetically sealed. Background leakage is less than 2 percent of full scale per day. Charger parts are mounted in solid block of conducting plastic; charges a dosimeter in 0.5 turn of knob.—*Landsverk Electrometer Co., Pippin Road, Cincinnati 31, Ohio.*

Mention No. 236 when filling out card.

Automatic Titrator

New automatic titrator accomodates beakers from 10-400 ml. capacity and takes all standard burettes down to 5



ml. Up to 4 delivery units can be used with 1 amplifier-control unit. Instrument uses maker's glass electrodes; can be used to measure pH and emf.—*Beckman Instruments, Inc., South Pasadena, Calif.*

Mention No. 237 when filling out card.

Laboratory Core-baking Oven

New "No. 3655" core-baking oven has working chamber 10 x 12 x 18 in.; maximum temperature is 550 F. Oven

draws 1000 watts on 110 or 220 v. 60 cps. Thermostatic temperature control is sensitive to 0.5 F.—*Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.*

Mention No. 238 when filling out card.

Quartz Monochromator

New monochromator passes white light from tungsten source through basal sections of optical quartz laminated to polaroid sheets. By synchron-

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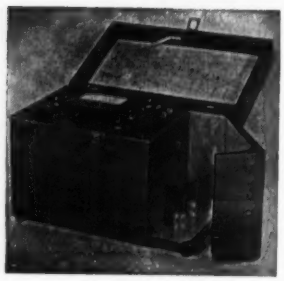
An S.S. White 100 Megohm Resistor is used as the plate load resistor for the first tube in the D.C. amplifier in this instrument which measures very small V.C. currents and voltages over an extreme range of values. The manufacturer, Beckman Instruments Division of National Technical Laboratories, says of the S.S.White Resistor "it has been very satisfactory"—which checks with the experience of many other electronic equipment manufacturers who use S.S.White Resistors.

Photo courtesy of National Technical Laboratories, So. Pasadena, Calif.



WRITE FOR BULLETIN 4906

It gives essential data about S.S.White Resistors including construction, characteristics, dimensions, etc. Copy with price list on request.

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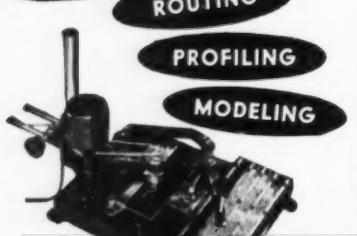

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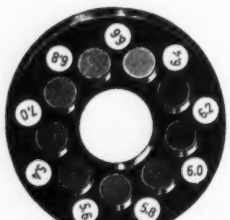

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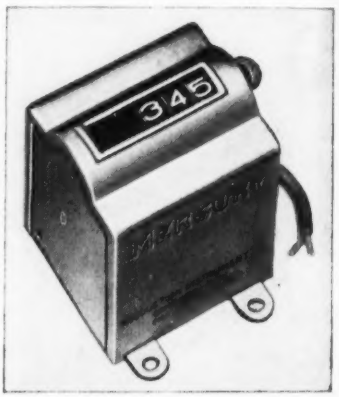
ous rotation of quartz sections wavelength of transmitted light can be varied continuously through visible spectrum. Instrument produces an average band width of 150 Angstrom units; light aperture is 1 in.—*Cambridge Thermionic Corp., 466 Concord Ave., Cambridge 38, Mass.*

Mention No. 239 when filling out card.

Small Electric Counter

New small electric counter with rollback reset is completely enclosed in a metal case with plastic window. Unit is actuated electrically from switch,



relay or photo-electric unit. Furnished with 1, 2, 3 and 4 digits for 6, 12, 24, 48 or 115 v., d.c. or 60 cps.—*Production Instrument Co., 702 W. Jackson Blvd., Chicago 6, Ill.*

Mention No. 240 when filling out card.

Heater for Opening Instrument Cases

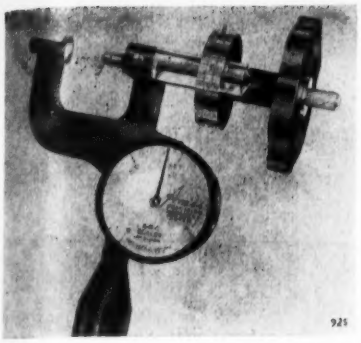
New application of maker's "Calrod" heating unit is designed to unsolder hermetically-sealed aircraft instrument

cases for maintenance away from factory. Controlled heat is applied to joints by heater bent to shape of instrument container and mounted in heat-reflective frame.—*General Electric Co., Schenectady 5, N. Y.*

Mention No. 241 when filling out card.

Portable Hardness Tester

New "Model 1" portable tester has diamond and ball penetrators for hardness reading of rounds and flats up to 1 in. Instrument reads in Rockwell A,B, and C scales. Anvils and penetrators are reversible for inside-wall testing



of tubes; soft alloys can be tested with large ball penetrators. Models available for samples up to 4 in.—*Ames Precision Machine Works, Waltham 54, Mass.*

Mention No. 242 when filling out card.

Automatic Sorting Gage

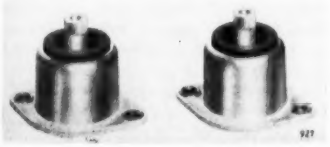
New "Model 144 B-12" automatic gage for sorting bushings measures over-all length. Pieces are separated

into 2 acceptable and over-and-under lengths. Maker's "Electricators" and power units are used.—*Federal Products Corp., 1144 Eddy St., Providence 1, R. I.*

Mention No. 243 when filling out card.

Air-damped Vibration Isolators

New "Series 6465" vibration isolators employ air damping; non-linear metal springs provide constant resonant fre-



quency over 2:1 load range. Load ratings are 0.1 to 3 lbs. per mount. Units are 1 in. diam., 1.03 in. high under load; weigh 0.25 oz.—*Barry Corp., 720 Pleasant St., Watertown 72, Mass.*

Mention No. 244 when filling out card.

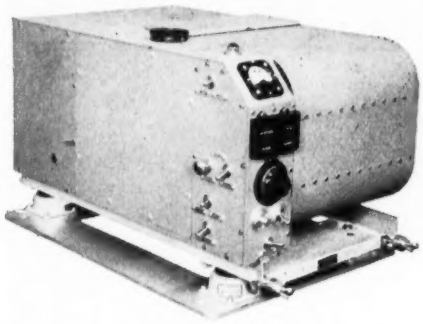
Wire-coating Thickness Controller

New "Model 493 B-80" controller uses maker's "Electricator" gage to measure thickness of coating extruded on wires up to 1 in. diameter. Thickness is controlled by varying wire

Century INDUSTRIAL

RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:

Size: 20" long, 12½" wide, 8⅞" high.

Weight: 60 pounds.

Number of Recording Channels: 6 to 50.

Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.

Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.

Paper speeds continuously and instantly variable without changing gears or sprockets.

Separate optical system for viewing before or during recording.

Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.

Data numbering at beginning of record.

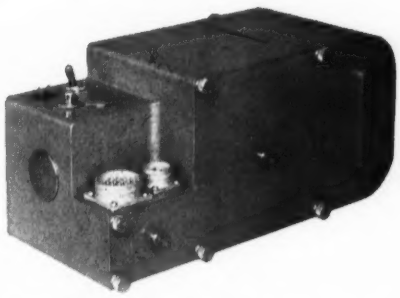
Footage indicator showing amount of paper remaining in magazine.

Automatic record length control.

Trace identification.

Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

Size: 5" x 5" x 11".

Weight: 11 pounds.

Cast Aluminum case.

Paper speeds variable ½" to 12" per second.

Detachable daylight loading magazine with a capacity of 3⅝" x 50' paper or film.

2 to 12 individual channels.

Trace identification.

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3. You get precise positioning of the moving contact because of the two bearings supporting the rotor assembly.
4. You get good rigid terminals because they are moulded integrally with the housing.
5. Terminals soldered to ends of resistance element before moulding. Entire resistance circuit is an integral part of the housing.
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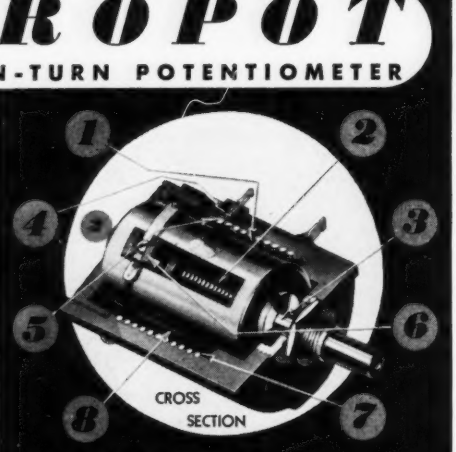

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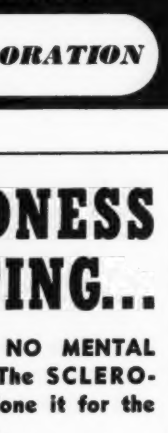

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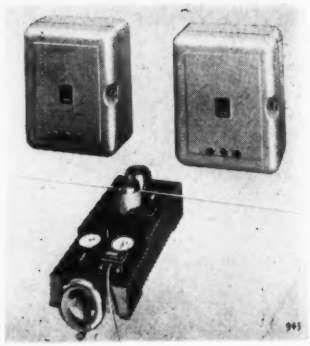

speed through extruder. Actual coated wire diameter is shown on dial-gage indicator.—*Federal Products Corp.*, 1144 *Eddy St., Providence* 1, *R. I.*

Mention No. 245 when filling out card.

Cylinder Speed-control Valves

New "Flo-Set" speed-control valves for air, water or oil are rated to 250 psi. and 250 F. Sizes available are 0.25, 0.375, and 0.5 in. Inside construction

is not damaged if excessive torque is applied during installation. All metal parts are aluminum except for stainless steel springs. Seals and poppets are molded synthetic.—*Hanna Engineering Works*, 1765 *Elston Ave., Chicago* 22, *Ill.*

Mention No. 246 when filling out card.

Microscope Slide Field-finder

New "Field Finder" for microscope slides consists of a slide with printed grid of 0.1 mm. graduations each mm. numbered or lettered. After desired field on slide is centered finder is substituted for slide and coordinates at center of field are observed and recorded on slide. To locate field later procedure is reversed. Units are interchangeable. —*Lovins Engineering Co.*, 8203 *Cedar St., Silver Spring, Md.*

Mention No. 247 when filling out card.

Glare-proof Coating

New "VB 248" coating is a baking finish adherent to stainless steel, designed to reduce glare from polished surfaces. It is available in black and all colors, in gloss and semi-gloss finish.—*United Lacquer Mfg. Co.*, 1001 *W. Elizabeth Ave., Linden, N. J.*

Mention No. 248 when filling out card.

of brilliant later contributors outshines the early work of the formulator as modern Mazdas outshine the first carbon-filament lamp.

Fact No. 7 is that this is a free country where everyone enjoys the right to define Instrumentation because this word has never been copyrighted. This right is enjoyed also by the founder and formulator—who now repeats that Instrumentation is a "horizontal" realm which includes Instrumentology as one of its specialized "vertical" provinces. This declaration, though accepted as a plain statement of fact in some circles, could be challenged as a mere opinion by Dr. Klopsteg. It should be supported. But that would take too much reprinting of old stuff. We simply report that ever since we designed and built our first instrument in the winter of 1904-05 we've known lots of instrument makers and users in labs and plants—civilian and military—and that whereas industrial instrument application almost always followed instrument conception and design in the old days, the situation has gradually changed. See our March 1940 editorial on lab and plant instruments where we discussed what Dr. Klopsteg calls "the long road" AND what we called "short hops" and "return flights." Today there are more and more of those return flights where practitioners of Instrumentation in industry lead and precede and teach practitioners of Instrumentology in laboratories. We assert that today Instrumentology grows faster as a segment of Instrumentation than it did when it was the know-how of the university or commercial instrument-maker. We opine that when in 1941 the American Association for the Advancement of Science decided (at the suggestion of our Company's President) to hold one-week summer conferences on "Instrumentation," it considered this subject a science; and that its nine summer conferences have been devoted to science, not to what Dr. Klopsteg says that Instrumentation "clearly denotes." We opine that when the American Institute of Physics published its scope-map in 1944 and showed Instrumentation as the only horizontal area, it had in mind the science which Instrumentation had become. We opine that 90% of the professional scientists who know the facts will not think that any "error" is to be "corrected."—MFB

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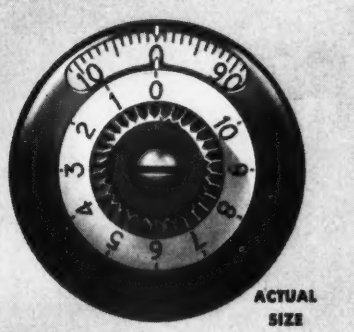

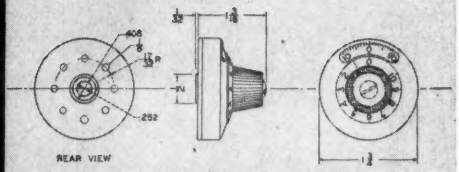

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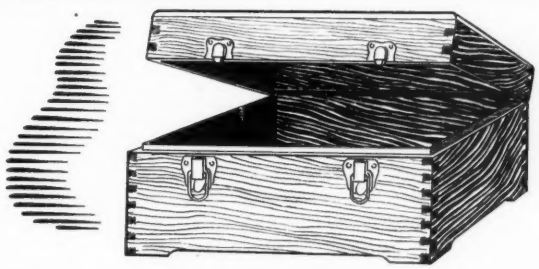

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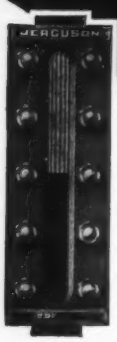

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Improved Ramberg Vacuum-tube Accelerometer

Recent research in the Engineering Mechanics Section of the National Bureau of Standards has resulted in an improvement of the Ramberg vacuum-tube accelerometer which NBS developed in 1946 for the Navy's Bureau of Aeronautics with the cooperation of Sylvania Electric Products, Inc. The new pick-up provides more sensitive and reliable acceleration measurements than did the earlier version which, despite slight erratic changes during its operation, has been successfully applied to both field and laboratory acceleration measurements. Among such uses have been acceleration measurements on pilot ejection devices for high-speed aircraft, in landing impact tests for model aircraft, as well as on aircraft in actual fiight.

The vacuum-tube acceleration pick-up is a twin-diode vacuum tube consisting of a fixed indirectly-heated cathode and two plates, one on each side of the cathode. The plates are elastically mounted so that they will be deflected if the base of the tube is accelerated in a direction perpendicular to the plane of the plates. The new model differs from earlier versions in having stops to limit the motion of the plates, support rods 0.01 inch in diameter to increase the sensitivity of the tube, and a second getter.

The primary design requirement met by the Ramberg vacuum-tube accelerometer is its provision for an electrical signal of sufficient strength to drive directly a high-frequency recording galvanometer and at the same time have a relatively high natural vibration frequency. In the operation of the original model erratic changes or "zero shifts" in its balance point were sometimes encountered. The source of this difficulty has been eliminated in the new model. The "zero shift," resulting from excessive accelerations to the pick-up while handling and installing, is prevented by stops which were added to limit the plate excursion and thus prevent overloading. "Zero drift," believed to be due to small fluctuations in the cathode electron emission, has been effectively reduced by three steps: First, the accelerometer was given an aging treatment which made its emission nearly constant; second, two "getters" instead of one were used to improve the electrical characteristics; and third, the sensitivity was increased by a factor of 25 to make the remaining random output negligible compared with the output due to acceleration.

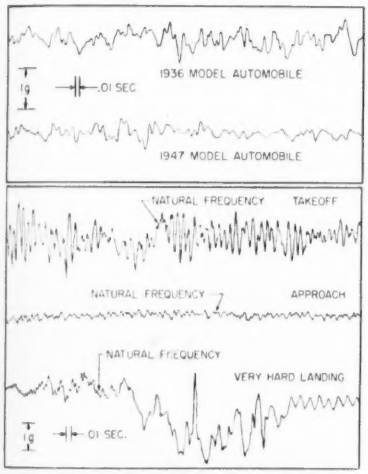
Because of promising results obtained with both the original and improved tube, an extended developmental project on the fundamentals of acceleration measurements is now under way as part of the NBS program on basic instrumentation, which is cooperatively supported by the Office of Naval Research, the Office of Air Research, and the Atomic Energy Commission. The objectives of this project are to obtain accelerometers having a greater range of acceleration measurement, higher output voltages, and damping of the natural frequency response. The accelerometers will be equipped with compact protective cases and mounting lugs for installation.

The improved Ramberg vacuum-tube accelerometer pickup consists of a twin-diode vacuum tube with a fixed indirectly-heated cathode and two plates, one on each side of the cathode. Visible within the tube envelope are the plates, the two "getters," the plate stops, and the support rods (lower center of envelope).

Field tests of the improved accelerometer have provided interesting and striking results that suggest the wide variety of uses to which such a sensitive device may be applied. For example, with the accelerometer clamped to the dashboards in 1936 and 1947 automobiles (and using a filter to eliminate natural frequency response), comparative records were obtained of the vertical accelerations to which the vehicles were subjected when crossing multiple streetcar tracks. Vertical accelerations experienced by the rear cockpit of a TBD airplane during takeoff, approach, and landing were likewise

recorded by rigidly clamping the accelerometer to the structure. The natural frequency response of the instrument itself at 160 cycles per second in these records is small compared to the response proportional to the imposed accelerations.

Variations in the vertical accelerations of a freight elevator going from the first to the second floor were also readily revealed by the accelerometer. The increase in acceleration when the elevator was put in operation, the nearly zero change in acceleration between floors, and the decrease in acceleration while stopping, were clearly shown in the continuous acceleration record. The natural frequency response is again small compared to the acceleration response. In this test, the circuit was modified by replacing a 1,400-ohm resistor in the filter circuit by one of 100 ohms. This resulted in a much higher sensitivity with some lowering



(Upper portion.) Tracings of oscillograms showing the vertical accelerations experienced by a 1936 and a 1947 automobile crossing multiple streetcar tracks. These striking comparative records were obtained by clamping the Ramberg vacuum-tube accelerometer to the dashboard of the two automobiles. The 1g calibration was obtained by reversing the tube in the earth's gravitational field.

(Lower portion.) Tracings of an oscillogram of the vertical accelerations to which the rear cockpit of a TBD airplane was subjected during takeoff, approach, and landing. The record was obtained by rigidly clamping the Ramberg vacuum-tube accelerometer to the structure. Note that the natural frequency response of the instrument itself (160 cps.) is small compared to the response proportional to the imposed accelerations.

of the attenuation at the cut-off frequency of the filter circuit.

The circuit used in the field tests of the improved pickup is an adaptation of the Kelvin double-bridge designed to minimize the effect of contact resistance both in the tube socket and in the adjustable rheostats. Because of the convenience of obtaining six volts from a storage battery, six volts were used for the heater voltage in these tests rather than the seven volts for which the heater is designed. A blocking filter was used ahead of the galvanometer to eliminate the possible 160-cps. output at the natural frequency of the accelerometer. The characteristics of the over-all circuit were found

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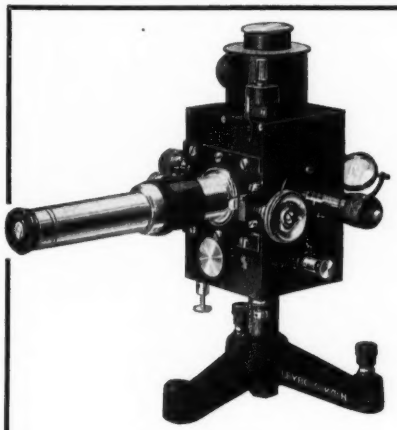

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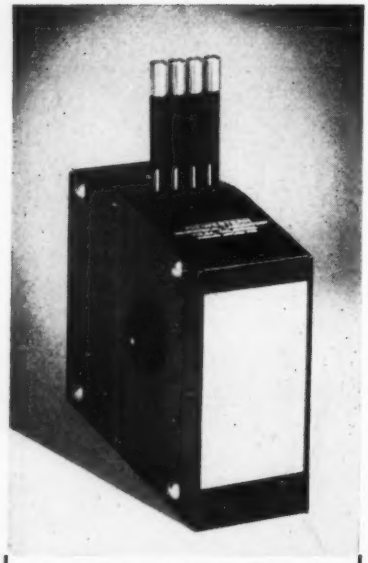

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As an indication of the efficiency of this new galvanometer, below are tabulated essential characteristics of two representative elements.

Type	Nominal Undamped Natural Frequency	Frequency Range Flat 5% A CPS	Undamped DC Sens. at 12" Opt. Arm MA/in.	Nominal Balance Displacement Per G*
102A	100	0-60	0.009	0.006"
2000	2000	0-1200	11.2	0.006"

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to be flat within five precent up to 20 cps. and to attenuate gradually to nearly 100 percent at 160 cps.

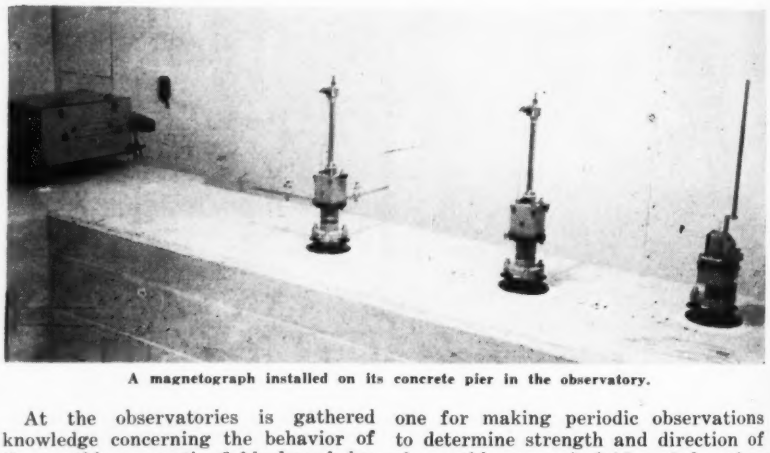
The accelerometer in its present form provides a useful addition to available measuring equipment for conducting field tests similar to those described above where accelerations up to about 5 *g* at frequencies up to about 20 cps. are to be measured. However, experience with the accelerometer indicates that it would be improved by the addition of a suitable protective cover with a convenient means for attachment, and by the provision of a mechanical means for damping vibration of the plates at their natural frequency. Work is now in progress to develop modified designs of the accelerometer to cover other acceleration ranges, as well as models having high plate resistance to give the high voltage output required for many electronic applications.

Third Magnetic Observatory in Operation in U.S.

HOUSTON, Tex.—A new magnetic observatory (third such observatory in the U. S.) is now in operation under the auspices of the U. S. Coast and Geodetic Survey at the University of Houston, Houston, Texas. The other two observatories are located at Cheltenham near Washington, D. C. and at Tucson, Arizona—too far from Houston to give reliable information for this area.

Geodetic Survey and Walter Ruska of the Ruska Instrument Corporation. Ruska offered to build and donate the instruments, and Captain Roberts promised the full support of the U. S. Coast and Geodetic Survey. The University of Houston furnished the site and buildings and operates the station under Dr. R. W. Long of the University.

Two small buildings were erected,



A magnetograph installed on its concrete pier in the observatory.

At the observatories is gathered knowledge concerning the behavior of the earth's magnetic field—knowledge necessary in maintaining accurate maps for air and sea navigation. The information is also important to the communication services and to the oil and mining industry which uses magnetic methods for exploration work.

Location of the observatory at Houston was decided following discussions between Captain Elliott B. Roberts, Chief of the Division of Geomagnetism and Seismology of the U. S. Coast and

one for making periodic observations to determine strength and direction of the earth's magnetic field, and the other to house delicate recording instruments which continuously record changes of strength and direction. The buildings are of wooden construction entirely non-magnetic, with concrete piers supporting the instruments. Copper nails and solid brass locks, hinges and other hardware were used, and all materials were checked for iron impurities. Even the ground over a considerable area around the building was checked for buried iron pipes and iron trash, and a water line near the building was relocated at a safe distance.

T. L. Skillman of the U. S. Coast and Geodetic Survey, Washington, D. C. makes base observations with the Ruska portable magnetic theodolite, as Walter Ruska, president of Ruska Instrument Corp., and Commander Curtis Lefever of the USC&GS watch.

Automatic Control Reduces Atomic-energy Plant Hazards

MILWAUKEE, Wis.—How automatic temperature, humidity, static pressure and air velocity controls are used to minimize the hazards in atomic energy plants was explained by J. A. Cutler, president of Johnson Service Co., Milwaukee, whose control systems are used extensively in atomic energy plants throughout the country. According to Cutler, there are currently three broad areas of application of automatic control apparatus in atomic energy

plants. As an initial consideration, he said, plants where radioactive materials are handled almost always are equipped with complete air-conditioning systems, and automatic temperature control apparatus is called upon to solve the same problems encountered in any first-class industrial building. Consequently, many thousands of standard regulators have been installed in these plants by Johnson engineers for operation in the usual manner. However, many special considerations arise because of the hazards of atomic energy work. For instance, a second type of control application is specifically related to the presence of radioactive materials, Cutler said. In most plants dealing with radioactive materials, this involves the precise control of the movement of air within each building to keep contamination at a minimum.

Cutler also explained that much of the space within a building handling radioactive materials may consist of hot-zone laboratories in which special fume hoods are installed for the treatment of materials. The use of these fume hoods, which are connected to exhaust ducts to provide a positive air movement to remove radioactive fumes and other toxic gases, has resulted in the development of the third and newest application of automatic control apparatus in atomic energy plants.

For safety, the velocity of the air through the hood door should be at least 125 feet per minute, he said. However, if this velocity is above 175 fpm., some radioactive particles undergoing processing are carried away. It is necessary, therefore, to control the velocity of air through the hood door between these limits. This problem is made more difficult because the hood door may be anywhere from wide open to almost completely closed and because of available resistance in the system when filters become dirty.

When fume hoods of this type were first proposed two years ago, Johnson engineers built a test installation, consisting of an exhaust system and two typical hoods, in its research laboratory. Exhaustive tests were conducted to develop a workable control arrangement. Several means of detecting changes of velocity were tried, including vanes, hot wires, and pressure differences. The vane system was found to be unstable; the hot wire method was influenced by air temperature as well as velocity, and was unable to differentiate as to the direction of air flow, Cutler said.

The pressure-difference method of velocity control, which finally was adopted at Argonne and Hanford as a result of the Johnson tests, depends for its operation on the fact that the velocity of air moving between two points is proportional to the difference in pressure between these points. In the case of air moving at a velocity of 130 fpm., this pressure difference is 0.001 inch water gage. To control the velocity at 130 fpm. within plus or

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minus 10 fpm. the control instrument must respond to pressure variation of 0.0001 inch water gage. The successful regulation of contamination in atomic energy plants by means of these automatic control installations is an economy measure as well as a health measure, according to Cutler, since expensive laboratory apparatus and equipment must be replaced if they become radioactive.

EDUCATION NEWS

MIT Offers Two Courses in Instrumental Analysis in Chemistry

Two one-week specialized training programs in instrumental analysis will be offered from July 9-13 and July 16-20 as part of the 1951 Summer Session at the Massachusetts Institute of Technology.

Dr. David N. Hume and Dr. Lockhart B. Rogers, both of the department of chemistry at M.I.T., will conduct the two courses, utilizing the facilities of the Institute's instrumental analysis laboratory.

The purpose of these programs is to provide for each type of instrumental method discussed (1) Adequate grounding in fundamental principles and theory involved; (2) Knowledge of wide variety of practical applications; and (3) Experience with available commercial instruments.

The first week, July 9 to 13, will be devoted to electrical methods of instrumental analysis, emphasizing potentiometry, polarography, conductimetry, amperometric titrations, and applications of self-balancing recording potentiometers. Optical methods of instrumental analysis, including spectrophotometry, colorimetry, fluorimetry, turbidimetry, nephelome'ry, and flame photometry, will be covered July 16 to 20.

Both programs will consist of a two-hour period for lecture and discussion and a three-hour laboratory workshop each day. Studies of the various methods will be designed to particularly help laboratory supervisors and practical analysts in selecting the best approaches to their problems.

Application forms may be obtained from Professor Gale at Room 3-107, Massachusetts Institute of Technology, Cambridge 39.

TECHNICAL SOCIETIES

AMERICAN SOCIETY OF TOOL ENGINEERS

Several papers on instrumentation for testing and quality control will be presented at the ASTE annual meeting in New York, March 15 to 17 inclusive. Papers will cover such subjects as non-destructive testing through the use of strain gages, supersonic inspection, etc.; optical inspection methods; continuous and automatic gaging and so on. Of interest to men who make or use instruments will be a paper on quality control by a Ford Motor Company manufacturing executive, one on automatic equipment controls, and others.

SOCIETY FOR APPLIED SPECTROSCOPY

The March meeting of the Society for Applied Spectroscopy will be held on Thursday, the 8th: 6:00 p. m., Informal supper at Tosca's, 118 Fulton St., 8:00 p. m., Regular meeting, Socony-Vacuum Training Center, 63 Park Row, New York. Speaker, Dr. Bert L. Vallee, Dep't of Biology, MIT. Subject, "Developments in a Backward Field—Trace Elements in Biology" (Emission spectrographic trace analysis and functions of such elements in biology). Technical Chairman, Roger W. Loofbourow, Merck & Co.

The April 3, 1951 meeting will be held at same hours and places as above. Speaker, J. T. Rozsa, National Spectrographic Labs., Cleveland. Subject, "Spectrochemical Methods in Ferrous Metallurgy." Technical Chairman, James Mellichamp, Squier Signal Labs, Ft. Monmouth, N. J.

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An Editorial

8719 New Instruments

BELOW is reproduced a tabulation of new instrument items which have appeared in *Instruments* each year during the 23 years it has been published.

Year	New Instruments	Progressive Total	No. of companies listed in the *Instruments Index*
1928	84	84	
1929	106	190	
1930	133	323	
1931	233	556	
1932	283	839	
1933	308	1147	
1934	311	1458	
1935	306	1764	692
1936	317	2081	
1937	313	2394	
1938	370	2764	
1939	363	3127	854
1940	291	3418	843
1941	246	3664	933
1942	266	3930	964
1943	280	4210	1013
1944	312	4522	1044
1945	393	4915	
1946	647	5562	1264
1947	660	6222	1307
1948	636	6858	
1949	798	7656	1361
1950	1063	8719	

A new instrument, as defined by *Instruments*, is any device which measures, inspects, tests or controls; or any product, which is an accessory or allied product, made by the manufacturer for the first time. Further a considerable change in the design or construction of an instrument also qualifies the product for inclusion in the "New Instruments" Section.

In the case of foreign new developments, these are only excluded if they are available through an office or representative in the United States.

A very interesting phenomena can be noted in the above table. Omitting the years from 1928 to 1931, which was a period during which the list of instrument manufacturers was being assembled, it will be noted that the annual number of new instruments from 1932 to 1945 inclusive is about 300. From 1946 to 1948 inclusive the annual number went slightly above 600. In 1949 the number went up to 800 and to 1000 in 1950.

During this period the number of instrument manufacturers increased. The first year that there was any indication of the number of companies in the Instrument Industry was in 1935 when the first *Instrument Index* appeared. The number of companies listed in that *Index* was 692. In the above table, column 4 shows the number of companies listed in subsequent issues of the *Instrument Index*. By 1949, the number was almost double the number in 1935. This increase is confirmed by the 1947 Census of Manufacturers as compared with the 1939 Census:

No. of Establishments Reporting in	1939	1947
Scales and Balances	56	75
Measuring and Dispensing Pumps	38	52
Electrical Measuring Instruments	59	154
Scientific Instruments	125	216
Mechanical Measuring Instruments	227	463
Optical Instruments and Lenses	31	114
Totals	536	1074

It is also interesting to note the Instrument Industry appears as a separate industry in the 1947 Census of Manufactures. For the first time the Instrument Industry was recognized by establishing code number 38 as "Instruments and Related Products." Even so there are still a number of Industries not included in this code but which are very definitely a part of the Instrument Industry. In the 1939 Census of Manufactures, the Instrument Manufacturers were reported as a part of the Miscellaneous industries. In the War Production Board during the Second World War instrument products were distributed among 22 of the 40 divisions.

For National Defense purposes, Instrument Manufacturers should be classified as mechanical, electrical, optical, etc. rather than as scientific or industrial. A scientific instrument is an instrument for which there is a small demand; when the demand increases it has become an industrial instrument.

Further all precision working industries should be assembled in one division in the National Production Authority as these industries represent a large number of man-hours per pound of material. Such a set-up will solve the most serious difficulty of the instrument industry—obtaining the necessary amount of raw material.

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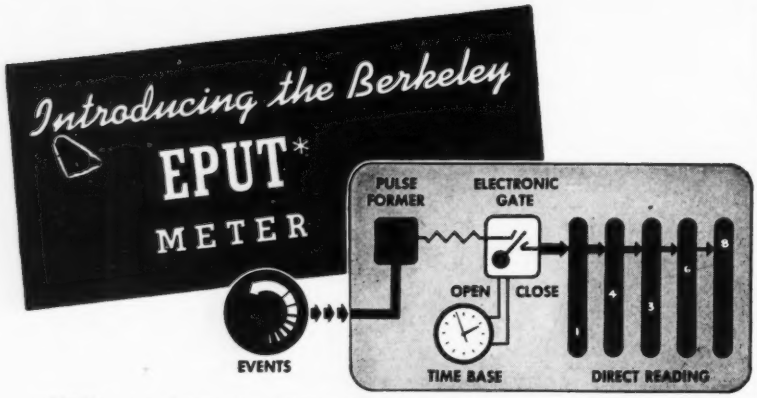

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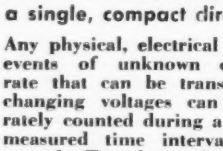

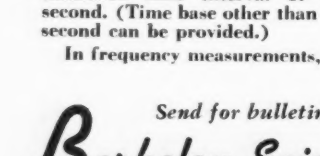

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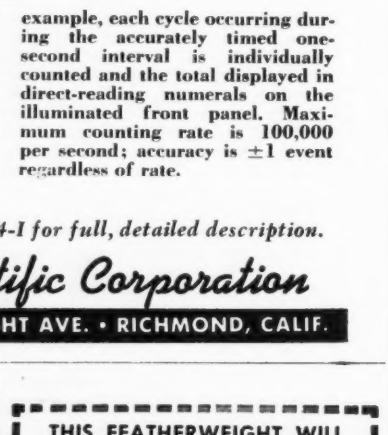

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DIFFERENTIAL MANOMETER

Continued from page 159

between the glass and the cover plate to prevent contact of these components, which might damage the glass. Cork or felt padding of uniform thickness proved satisfactory for this need.

Appropriate openings were bored and threaded into the ends of the main body block to permit installation of the glass tubes and accompanying seals. Where necessary to seal the tubes from the body two 5/8 in. neoprene "O" rings and a thin steel washer are installed, followed by a gland nut to apply compression to the seals. The holes are then sealed by means of plug bolts equipped with copper washer seals. The gland nuts and plug bolts mate the same threads. The two plug bolts at the top of the manometer were drilled completely through and then tapped for accommodation of exterior connections. This method of installing the tubes permits their removal for cleaning and replacement without disassembly of the major components.

This manometer is considered suitable for use at pressures up to 3000 psi. (the recommended pressure limitation of the neoprene seals) if they are installed in accordance with the specifications of the manufacturer. Periodic inspection of these seals has indicated that they will function satisfactorily when installed as described herein. The glass plates do not appear to be stressed to dangerous proportions. Maximum shear stress in these plates is approximately 800 psi. when the internal pressure is 3000 psi. This value is well below the yield point for tempered glass.

The manner in which the manometer is constructed requires that differential heads be determined by means of a remote viewing instrument, such as a precision cathetometer. This method of viewing the menisci may result in illumination difficulties owing to the recessed position of the glass tubes. Care must be exercised in lighting the liquid columns to avert the possibility of creating shadows on the meniscus, which would result in erroneous readings. This difficulty can be eliminated satisfactorily by applying an intense spotlight on each column from the approximate height of the meniscus under observation. Painting the metal directly behind the tubes white or yellow will produce good contrast when the manometer fluid is mercury. For clear fluids red paint is recommended. Owing to the absorptivity of air by liquids under high pressure, mercury should be employed when the instrument is under more than several atmospheres pressure.

This instrument has functioned satisfactorily for the precision determination of differential heads at pressures exceeding 1000 psi. No leaks have been encountered in any of the internal or external seals. Viewing the liquid columns through the thick glass plates does not appear to introduce any errors which might be attributed to distortion of the light rays. Except for its considerable bulk it has proved to be the

most satisfactory solution to a difficult instrumentation problem.

Acknowledgment. A major portion of the expense of developing this instrument was defrayed by The National Advisory Committee for Aircraft.

WATCH BALANCE WHEEL

Continued from page 155

wheel motion closely enough for practical purposes. In the instrument here described the natural frequency of the suspension system and watch was one-third to one-fifth cps., depending on the moment of inertia of the watch, corresponding to a frequency on the order of one-tenth that of the balance wheel. It is interesting to note that when the natural frequency of the watch and suspension system is greater than that of the balance wheel the motion of the watch is *in phase* with the balance wheel, while with a natural frequency less than the balance wheel frequency, as in the present case, the motion is of opposite phase.[2]

The equipment described readily permitted a determination of the watch rate by comparison with the 60-cps. power line frequency. The curves on the oscilloscope screen moved to the right for a watch gaining, and to the left for a watch losing. The rate was determined by timing the motion of a point of the curve similar to the procedure described by van Suchtelen.[3] A check of the power line frequency as a time standard was made by comparing the indications of an electric clock with the time signals of radio station WWV of the National Bureau of Standards. This comparison showed that the power line frequency near Washington, D. C. could not be used for precise timing of watches, but was sufficiently constant for approximate timing. The power line frequency was satisfactory for the work described here since the production of a curve of balance wheel motion was the primary object rather than precise determination of watch rate.

It has been shown that the motion of the suspended watch case changes the rate of the watch.[2] In the present case, the rate of a watch is changed by an amount $\lambda/2$, referred to unity as the error plus the timing interval with the watch stationary. When the balance-wheel frequency (watch stationary) is greater than the natural frequency of the suspended watch, the balance-wheel frequency increases when the watch case is allowed to oscillate. Thus the rate of the watches tested changed (watch gaining) by about 5 seconds per day for wrist watches and about 25 seconds per day for a large pocket watch. For use of the instrument for timing watches this error can readily be reduced to one second per day or less by adding weights to suspension system to reduce value of λ.

Derivatives of the curves of Fig. 4 can be prepared graphically to show angular velocity and angular acceleration of the balance wheel. A curve of acceleration would appear to be of particular interest since this curve would provide a record of forces acting on

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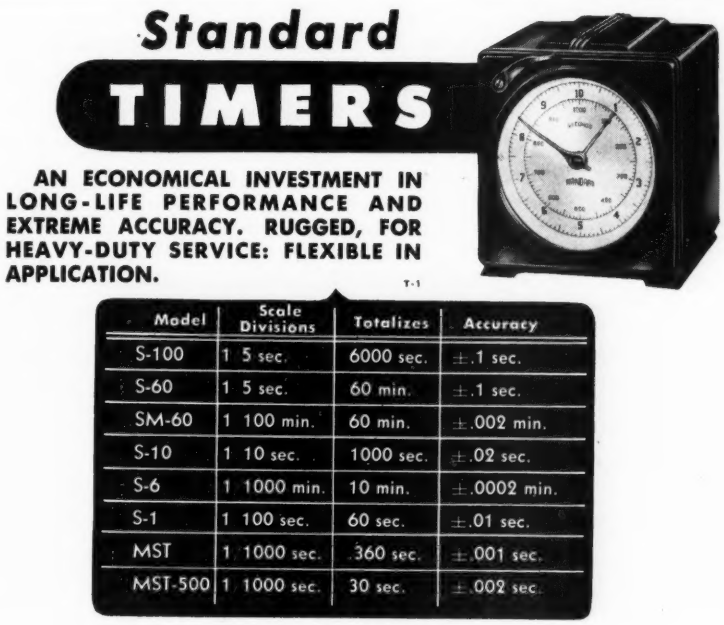
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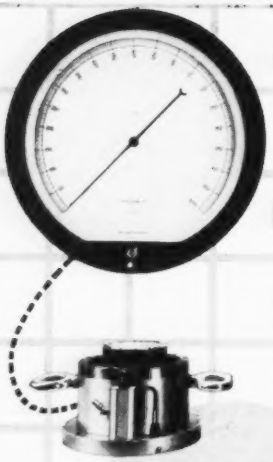

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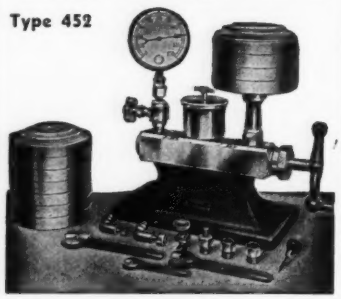

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the balance wheel throughout its travel, and a curve of acceleration with the fundamental component removed would show directly the characteristics of the impulses received by the balance wheel from the escapement.

An attempt was made to obtain a curve of acceleration directly on the oscilloscope screen. The equipment used was similar to that shown in Fig. 1 except that the watch holder shown was replaced by a holder incorporating a variable resistance type phonograph pickup.[4] The phonograph pickup comprised a sensitive resistance type strain gage made by coating a conducting layer of carbon on the opposite surfaces of a small cantilever beam of plastic material. The watch was supported on a pan arranged so that the movement of the watch deflected the cantilever beam, the amplitude of motion of the watch being constrained by the beam to a small part of the free amplitude. The strain gage was connected in a bridge circuit supplied from an oscillator, and the bridge output connected to an oscilloscope through a phase-discriminating amplifier similar to the arrangement described by Savic.[5] This equipment was not successful in producing a usable trace, primarily because of difficulty in balancing the bridge circuit. Had it been possible to balance the bridge circuit, a higher order of amplification would have been required.

An attempt was made to obtain a curve of balance wheel velocity directly on the oscilloscope by placing the movable coil of the watch holder of Fig. 1 in a steady magnetic field. It was estimated that this arrangement produced a 2.5-cps. signal of approximately 50 microvolts amplitude at the coil terminals. The difficulty of constructing an amplifier having the necessary voltage gain at this low frequency precluded the use of this arrangement.

By the use of equipment more suitable than that available to the writer, the methods described for obtaining curves of acceleration and velocity would probably provide usable results. Limitations in the equipment available made it impossible to obtain curves of balance-wheel displacement of the precision that would be obtainable with more refined equipment; further, it was not possible to carry out a comprehensive schedule of tests. Accordingly, the results given are necessarily of a qualitative nature, but serve to illustrate the practical operation of instruments deriving a signal from a watch balance wheel by case reaction.

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(4) R. S. John, "A Strain-sensitive Phono Pickup," *Radio and Television News*, Vol. 43, No. 2, February 1950.

(5) P. Savic, "The Wire Resistance Strain Gauge," *Research*, Vol. 1, No. 3, December 1947.

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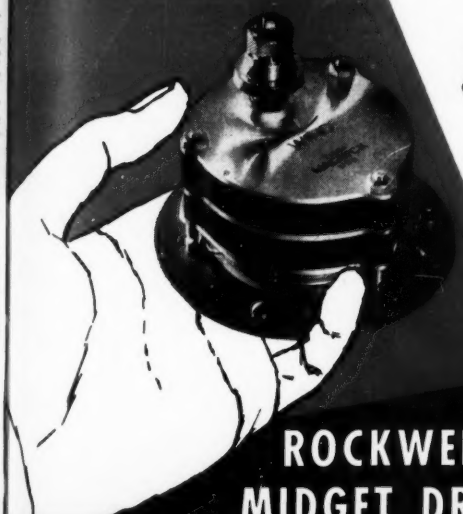

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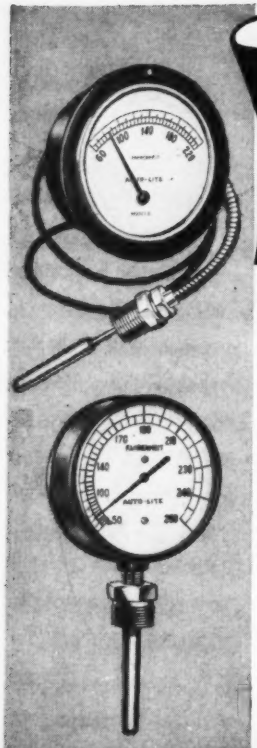

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Continued from page 157

with a 0.003-in. diaphragm and a supporting grid having twenty holes (Fig. 4, Test No. 1). A 0.0015-in. diaphragm was then substituted and the test repeated under identical engine operating conditions (Fig. 4, Test No. 2). If the inertia of the diaphragm is significant the two indicator cards thus obtained should be shifted somewhat with respect to each other. This does not appear to be the case and diaphragm inertia may thus be neglected. The same test was repeated a third time with the original diaphragm but using a supporting grid with forty holes. Since this will halve the time required to fill the cavity under the diaphragm, an effect must be observed if that time is significant. As before no appreciable time lag was actually observed (Fig. 4, Test No. 3). In order to determine the characteristic time of the relay circuit, a contactor was geared to the crankshaft of the engine and used to trip the relay circuit once every two revolutions. The relay circuit was thus triggered at the same crank angle under all engine operating conditions. If the characteristic time of the circuit is long, the spark mark on the drum will be shifted by an amount depending upon engine speed. Tests were conducted at speeds between 0 rpm. (manual turning of engine) and 1700 rpm. The spark marks were found to coincide at all speeds, thus showing that the characteristic time of the circuit is short compared to the engine speed.

On the basis of the tests described above it may be concluded that the indicator performs with the desired accuracy. The kind of data that were obtained with it are illustrated in Fig. 5, which shows an engine indicator card obtained at an engine speed of 1400 rpm.

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TABLE OF CONTENTS

Section Secretaries Meeting Data and Programs 14
A Message from the President 15
Pittsburgh Section Conference 15
Instrument and Control Maintenance
By J. H. Cuthbert 16
One Knob Production Control by C. F. Adeszko 19
Mass Spectrometer
By Robinson, Washburn, Berry and Perkins 25
Employment Service 29
New Jersey Section Symposium 29

THE SECRETARY'S PAGE

Richard Rimbach

1951 Membership Campaign

THE fifth anniversary membership campaign of the Society is well on its way. The efforts of all Section presidents, directors, secretaries, membership committeemen and members have been enlisted in this effort to increase the total Society membership rolls to well over 5000 members by April of this year.

The National Sections and Membership Committee, under the direction of M. S. Jacobs, has asked Section officers to subject their respective areas to a critical re-examination with a view to increasing Section membership by awakening Society interest among heretofore overlooked instrument engineers and instrument men who would benefit by membership. Sections are being asked to contact lapsed members and to revive the interest of these men in Society activities. Section membership committees are being newly organized and expanded.

Every Section of the Society has a huge untapped membership potential in its area. This potential is the main objective of the campaign. Every member of every Section, whether he has been officially appointed to a membership committee or not, should consider himself a spokesman for his Section and an individual center of membership promotion activity. Every member must know at least one other individual who is not now a member, but who should be. Most members know many other individuals who would be of value to the Society and who would find Society membership profitable, but for one slim reason or another, fail to sign up. These latter are the men who must be reached. If every member will assume the responsibility of overcoming this inertia of his non-member working associates by encouraging them to join

Continued on page 15

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
E. J. Burda, Sandia Corp., P. O. Box 5800, Albuquerque, N. Mex. Tel: 5-5511
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
E. H. Pfeffer, P.O. Box 291, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.
First Tuesday, 7:15 P. M., Engr's Club.

ATLANTA
D. M. McRae, 150 Nassau St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

BALTIMORE
W. A. Dickinson, 2716 Dunbrook Ct., Baltimore 22, Md. Tel. Dundalk 2272J
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge. La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., 99 Club, 99 State St.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P.M., Carolina Dines.

CENTRAL ILLINOIS
Thomas A. Carroll, 721 Hurlburt St., Peoria 6, Ill. Tel.: Peoria 4-8909
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.
March 7, "Principles of Automatic Control," ISA Color & Sound film by G. F. Akins, J. Kowalski, E. Kodak Co.

CENTRAL INDIANA
Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
Karl W. Robertson, Minneapolis-Honeywell Reg. Co., 121 W. Onondaga St., Syracuse, New York.

CHARLESTON
Fred Gilmer, 415 Bibby St., Charleston, W. Va.
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel
March 5, "Telemetering," W. E. Rufleth, Bristol Co.
April 2, "Design of Electrical Systems for Measurement and Control," C. L. Saunders, Wheelco Inst. Co.

CHICAGO
Floyd E. Ertsman Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Shoreland Hotel.
March 5, "Basic Errors in Testing," W. A. Wildhack, Natl. Bur. Stds.
April 2, "Unattended Booster Station on Pipe Lines," J. P. Heddin, Standard Oil Pipe Line Div. Regional Joint Meeting with Northern Indiana Section.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

CINCINNATI
L. W. Greene, 181 Market St., Aurora, Ind.
Second Monday, Meeting at 8:00 P.M., Eng'r. Society Hqs.

CLEVELAND
A. E. Ehrke, 5805 Euclid Ave., Cleveland, Ohio. Tel: WI 3-1036
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.

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W. C. Myers, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio. Tel: UN 3191, Ex. 248
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

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Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.
March 20, "Engine Indicators," E. Gillig, Ethyl Corp.
April 17, "Recent Developments in Cathode Ray Oscilloscopes," S. Sterling, S. Sterling Co.

EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday. Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
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Last Monday, 8:00 P. M., Engineers Club.

KANSAS CITY
L. E. Oberhelman, Standard Oil Co., Sugar Creek, Mo. Tel: MU 1227
First Tuesday, Meeting at 7:30 P.M., Univ. of Kansas City.
March 6, "Coordinated Control Systems and Graphic Panels," A. F. Sperry, Panellit, Inc.
April 3, "High Pressure Instrumentation," C. E. Balcerzak, Bur. Mines, Louisiana, Mo.

LOUISVILLE
C. M. Bosworth, 203 Arbor Park, N., Louisville, Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
S. J. Mizuhara, 1075 Allard, Verdun, Quebec, Canada. Tel: TR 3252
Last Monday, 8:00 P. M., Mechanics' Institute.

NEW JERSEY
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First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House, Newark.
March 6, "Pneumatic Computing Relays and Their Place in Control Circuits," M. J. Boho, Hagan Corp.
April 3, "Panel Board Design," Symposium beginning with luncheon at noon, and resumed after dinner in the evening. Essex House Hotel.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

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F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.
Feb. 26, "Manometer Applications in Industry," A. A. Hejduk, Vice-pres., Meriam Instrument Co.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 22, N. Y. Tel: GR 1450
Fourth Monday, Dinner at 6:00 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.
Feb. 26, Inspection Trip to Westinghouse plant at Cheektowaga, N. Y.
March 26, H. W. Barrett, Buffalo Meter Co.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
S. D. Stillson, 1324 Everett St., El Cerrito, Calif. Tel. Becon 2-7139
Third Monday, 8:00 P. M., E. Bay Area.
March 19, "Gyroscopic Principles & their Uses," N. Thompson, Sperry Gyroscope, East Bay.
April 16, "Basic Control Instrumentation," Paul Hoyt, Shell Dev. Co. East Bay.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776
First Wednesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
John H. Clark, 230 Canton Hall, Oak Ridge, Tenn. Tel: 5-9142
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Oak Terrace.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
R. E. Harris, 228 Mays Bldg., Amarillo, Texas. Tel.: 31434.
Third Tuesday, Meeting at 8:00 P.M.

PHILADELPHIA
R. R. Trenner, Rm. 306, 3147 Broad St., Philadelphia 32, Pa.
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.
Feb. 21, "Instrumentation Problems Encountered on his recent trip to Europe," A. Krieg, Socony-Vacuum Oil Co.

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa. Tel: HI 1-1800
Fourth Monday, meeting jointly with the Technical Committee on Inspection and Gaging. Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.
Feb. 26, "An Improved Pneumatic Control System," R. E. Clarridge, Taylor Inst. Co. Inspection Committee Speaker: N. Bowers, American Petroleum Institute, "Inspection Practices in European Pipe Mills."
March 28, 29, "Instrumentation in the Steel Industry," two-day conference, ten papers. Carnegie Inst. Technology.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.

RICHLAND
R. A. Nederhood, 2003 Trippe, Richland, Washington. Tel. 5-4442
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
J. J. Connors, 272 Elgin St., Sarnia, Ontario, Canada. Tel: 1970 W
Second Friday, 8:00 P. M., Moose Hall.

SOUTH MICHIGAN
W. J. Sprau, 2509 S. Rose St., Kalamazoo, Mich. Tel: 4-7012.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Thursday. Meeting at 7:30 P.M., Garner Aircraft Instrument School.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516
First Wednesday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.
March 7, "Coordinated Control Systems and Graphic Panels," A. F. Sperry, Panellit, Inc.
April 4, "High Pressure Instrumentation," C. E. Balcerzak, Bur. Mines, Louisiana, Mo.

TOLEDO
Morris L. Conner, 925½ Sherman St., Toledo, Ohio. Tel: MA 9403
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.
March 3, "Principles of Automatic Control," ISA Color-Sound film.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J
No definite night, Dinner at 6:45 P.M., Meeting at 8:00 P.M., Hall's Dining Rm., Bristol Hwy., Kingsport.

TULSA
J. J. Fox, Phillips Petroleum Co., Phillips Bldg., Bartlesville, Okla. Tel: 6600 Ext. 501.
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.
March 5, "Coordinated Control Systems and Graphic Panels," A. F. Sperry, Panellit, Inc.
April 2, "High Pressure Instrumentation," C. E. Balcerzak, Bur. Mines, Louisiana, Mo.

TWIN CITIES
Alden Hine, c/o Pinkney & Hine, 552 Plymouth Bldg., Minneapolis 3, Minn. Tel.: Lincoln 0523.
Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union, U. of Minn.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.
April 16, "Principles of Automatic Control," ISA Color-Sound film.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan. Tel. 0167J
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.
Feb. 20, "Principles of Automatic Control," ISA Color-Sound film.

WILMINGTON
J. E. Charsha, Jr., Hammel-Dahl Co., 1000 Washington St., Wilmington 11, Del.
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

A Message From The President

ON JANUARY 17, 1951 the Instrument Society of America was five years old. It was on that date in 1946 that the tenth of the local organizing groups ratified the original Constitution and By-Laws, which meant that, according to the agreement of the organizing groups, the Society came into official existence. The first meeting of the Board of Directors was called to order by President A. F. Sperry in Detroit on April 5, 1946. Approximately 1100 members were represented by the Directors at the meeting. In September, the first Conference and Exhibit was held in Pittsburgh.

In these five years, the Society has developed a practical operating structure, achieved a sound financial position, grown geographically to include practically all important centers of the use of instrumentation, and achieved national and world-wide recognition as a vital factor in technology.

Conferences and exhibits have also been held in Chicago, Philadelphia, St. Louis and Buffalo. The number of sections has increased to 51, and the membership to over 4300. The Society has achieved full recognition for its technical accomplishments, a single example being the participation in the annual conference by such organizations as The American Institute of Physics, The American Society of Mechanical Engineers, The American Institute of Electrical Engineers and The Institute of Radio Engineers. We can take pride today in the status of our Society in the industrial and technical fields.

Financially, the history is very sound. The Board of Directors has shown wisdom in keeping expenditures within income. However, this has been possible, and the life of the Society has been possible, only due to the profits from the annual Exhibits. Means must be found to relieve this dependence. If, due to war or other emergency conditions, it becomes impossible to hold an Exhibit, supplemental means of income will have to be developed to replace the Exhibit profit. In addition, a sharp increase in the expense of operating the Society must be expected, due to two reasons. The first is the general increase in price level, and the second is the necessity of relieving Secretary Rimbach of the burden of office, which he has been carrying without compensation ever since the start of the Society. The Executive Committee, and the Society Structure and Planning Committee, are studying this question diligently, but to date have found no easy answer.

Future growth of the Society will occur in the increase in membership of existing Sections. Our geographical coverage by now is substantially complete, and it is not to be expected that any great increase will occur in number of Sections. However, great opportunities do exist for serving the needs of technicians and engineers in fields which we have covered in our national structure and meetings, but have not covered intensively in our local activities. Probably, the outstanding example is in the field of inspection and gaging. In this case, the Pittsburgh Section has already shown that every metal-working center possesses a large, untapped body of potential membership whose needs are not being served at present by ISA, or any other Society.

In the Pittsburgh Section program, joint dinner meetings are held, after which the parent group holds its technical program, while the inspection and gaging group holds its own meeting separately. Two or three other Sections are starting activity in this field, and I strongly urge all Sections, particularly those where there are substantial numbers of metal working plants and machine shops, to start promotion of this activity. In the light of present world conditions, this is not only desirable from the standpoint of the Society, but a patriotic duty. The Sections and Membership Committee will be very glad to assist in making a start in such activity.

Other fields in which our efforts have been rather sporadic have been those of Analysis, Transportation and Testing. These will be very rewarding to Sections which will put some time, thought and energy into providing facilities for the expression of the interest of technical people engaged in such work. It is in such fields, where methods and apparatus are not standardized even to the small extent of those in the industrial field, that technicians and engineers, research physicists and chemists, instrument makers and designers, will find the interchange of ideas and methods most helpful.

There are other fields of application and instrument design, such as radiation and biochemistry, which we have not attempted to cover as yet, either nationally or locally. The Technical Division is studying the desirability of starting activity in these. Undoubtedly, there is valuable work to be done in them, but it is my very strong feeling that the most valuable work that can be done in the Society at the present time is the development by the local Sections of the increased membership possible from the latent interest in fields which the Society is already supposed to cover. Results of the efforts of some Sections show that the growth is possible. All that is required is some hard, thoughtful work by members and officers of local Sections. The results will be very rewarding to those who make the effort.

—J. B. McMAHON, *President*

PITTSBURGH SECTION CONFERENCE

"Instrumentation in the Steel Industry"

The Pittsburgh Section of the Instrument Society of America with the Carnegie Institute of Technology will cosponsor a conference on "Instrumentation in the Steel Industry." The meetings will be held March 28 and 29, 1951 at Carnegie Institute of Technology in Pittsburgh, Pa.

The Pittsburgh Sections of the following National Societies are cooperating with the Instrument Society: the American Institute of Electrical Engineers, the American Institute of Mining & Metallurgical Engineers, the American Iron and Steel Institute, the American Society for Metals, the American Society of Mechanical Engineers, the American Society for Testing Materials, the American Welding Society, and the Engineers Society of Western Pennsylvania.

All industries are urged to send their engineers and production men to these sessions offering information of value to their companies. Further details can be obtained from H. R. Fulton, Publicity Chairman, 902 Oliver Building, Pittsburgh.

CONFERENCE PROGRAM
FORUM ON PNEUMATIC, HYDRAULIC AND ELECTRIC SERVOMECHANISMS

The forum will be conducted by a three-man panel composed of the following members:

Elwood T. Davis, Leeds & Northrup Company, who will present a paper on *"Electric Servomechanisms"*; H. Ziebolz, Askania Regulator Company, the paper on *"Hydraulic Controls"*; and A. A. Markson, Hagan Corporation, the paper on *"Pneumatic Controls."*

Other papers include:

"Comparison of Methods of Measuring Molten Metal Temperatures" by J. W. Percy, U. S. Steel Corporation.

"Instrumentation in Controlling the Welding Variable" by Julius Heuschkel, Westinghouse Electric Corporation.

"Instrumentation and Control in the Utilization of Mixed Fuels and Oxygen in Open Hearth Furnaces" by Martin J. Conway, Consulting Engineer, and Edward H. Cauger, Wheeling Steel Corporation.

"High-speed Reheating of Seamless Steel Tubes" by H. W. Cox, National Tube Company.

"Methods for Sorting Mixed Metals" by Anthony Doschek of Doschek Associates.

"A Thermal Couple System for Molten Metal Temperature Measurement" by Lester Veiock, Heppenstall Company.

"The Industrial Application of the X-ray to the Inspection of Steel Castings" by J. N. Flanagan, Pittsburgh Ordnance District, Ordnance Corps., U. S. Army.

George E. Breece

It is with deep regret that the New Jersey Section announces the death of their member George E. Breece. He had been a member of this section since April 1948.

David P. Lupton

The Wayne County Section, ISA, sorrowfully announces the death of one of its members, David P. Lupton, of Huntington Woods, Mich. Mr. Lupton, a member since October of 1949, died November 14, 1950.

1951 MEMBERSHIP CAMPAIGN

Continued from page 13

and attend Section activities, the Society expansion will necessarily follow.

Sometime ago on this page there appeared an article entitled "Ten Ways to Kill a Society," a negative approach designed to illustrate the methods of Society participation. Here is the positive side:

Go to your Section meetings. Arrive early. Go out of your way, break other engagements to attend the meetings. Cooperate with your fellow members. Accept office. Accept committee appointments and contribute to the work of the committees. Give your opinion freely, speak up. Do more than is necessary, work unselfishly. Pay your dues promptly. Get new members. Talk up the Society to your fellow workers.

Instrument and Control Maintenance In A Steel Mill

By J. H. CUTHBERT *

Abstract. This paper discusses the instrumentation of a large steel mill, and some of the problems encountered in metering and controls. Brief description is given of experimentation on Noble thermocouple compensating lead wire. Adequate shop facilities and trained personnel are prime requisites of an efficient instrument department. The paper also describes laboratory equipment.

Instrumentation in a large industrial plant differs so widely from a utility plant, that the organization and function of an instrument service department presents many unusual and interesting problems. Each instrument department in the various plants will encounter conditions peculiar to the industry, or branch of industry, that it services. This paper, describing the instrument maintenance in a large steel plant, will deal directly with steel mill problems.

During the past several years, the steel industry has become increasingly conscious of instruments and instrument control. The rising cost of labor and material demands, more than ever, economy of operation and closer adherence to specifications. In view of this situation more and more responsibility has been placed on instrument departments for closer quality control and the use of thoroughly trained personnel. The problem of training this personnel has been lessened noticeably in recent years through the introduction of a training course for instrument repairmen apprentices.

The meter and instrument department of a large steel plant is, of necessity, divided into groups or sub-divisions consisting of: 1. Electrical Meter Group, 2. Pyrometric Group, and 3. Mechanical Group.

Each of these groups should contain instrument men trained for specific problems peculiar to the equipment they service, such as:

The Electrical Group must be qualified to install, maintain and repair: (a) a.c. and d.c. electrical indicating instruments, (b) a.c. and d.c. electrical recording instruments, (c) a.c. and d.c. watthour meters, and (d) a.c. and d.c. power relaying equipment. Maintain, repair and calibrate: (a) portable rotating standards, (b) portable indicating standards, (c) repair and test instrument transformer equipment, and (d) understand switchboard wiring — layout and wire meter and relay panels.

The pyrometric group should be qualified to install, maintain and repair: (a) thermal type temperature indicating and recording equipment, (b) millivolt-meter type indicating and recording equipment, (c) mechanical type potentiometer indicating and recording equipment, (d) electronic type potentiometer indicating and recording equipment, (e) fabricate, test and repair base and noble metal thermocouples, (f) install, calibrate, maintain and repair optical and radiation type temperature indicating and recording equipment, (g) maintain, repair and calibrate laboratory and portable type potentiometer standards, and (h) install, maintain and repair mechanical, electrical and electronic types of pyrometric equipment.

The Mechanical Group should be qualified to install, maintain and repair: (a) pressure and thermal types of indicating and recording meters, (b) positive displacement types of flow metering equipment, (c) diaphragm, pilot operated and electrical types of pressure, liquid level and flow controls, (d) orifice type mechanical, indicating and recording flow metering equipment, (e) pneumatic and hydraulic controls for flow, combustion and liquid level, and (f) electronic type flow, combustion and liquid level controls.

From the above listing we can realize the prodigious amount of specialized maintenance responsibility incurred in a steel plant instrument department.

To carry out this responsibility the instrument shop or laboratory must be designed to accommodate the various types of precision equipment required to test these facilities adequately. Storage space must be provided to stock the thousands of spare parts that are required to service this equipment. Proper facilities for housing of precision standards and extreme care in handling same, is of utmost importance.

In directing attention to the photographs, we observe that Fig. 1 illustrates an electrical test board in the laboratory, designed to test any type of electrical instrument. The switches and terminals can be arranged to supply a.c. or d.c. volts, a.c. or d.c. amperes, millivolts, and power factor.

Fig. 2 illustrates a laboratory test furnace having a range of zero to 2400° F., used for testing base and noble metal thermocouples. A semi-precision potentiometer is used for this testing, with a radial switch for cutting in the different thermocouples under test. The furnace temperature is controlled by the two instruments above the furnace. The upper instrument controls the furnace by thermocouple up to 1600° F., at which point it automatically cuts in the lower instrument which then controls the furnace by rayotube up to 2400° F.

Fig. 3 illustrates the test equipment used for calibrating optical pyrometers.

Fig. 4 illustrates the test equipment used for calibration of positive displacement meters.

Considerably more equipment than that exhibited on the slides is required to establish a complete instrument laboratory for servicing industrial instruments.

Primarily, it is the duty of engineering or research units to specify the instrumentation and installation on new equipment, while the instrument service department accepts responsibility for its subsequent efficient operation. This condition places considerable stress upon the technical ability of the serviceman, since his duties, while theoretically restricted to the instrument itself, also require that he must know good installation practice and its relation to control of various processes.

The open hearth represents one of the greatest challenges to instrument control engineers. It is the largest consumer of fuel, per ton of product, in the steel industry and the most difficult unit in which to apply standard instrument equipment. Most open hearths require costly maintenance because of atmospheric conditions both inside and outside the furnace area. Extremely high temperatures are created which are usually beyond the range of all but rare metal and radiation equipment. Excessive vibration and high ambient temperatures are very common.

Standard equipment on the modern open hearth includes instruments and controls that require continuous and diligent maintenance and is usually equipped with pneumatic or hydraulic controls, or both; temperature recording and controlling devices; furnace pressure recording and controlling; various flow indicators; pressure indicators, and smoke recorders. This equipment includes checker temperature recorders; radiation units for controlling roof temperatures; fuel-air ratio controls; oil to gas ratio controls; automatic reversing controls and bath, or liquid steel temperature recorders.

Bath temperature recorders have improved in design during the last two or three years and apparently will soon qualify for acceptance as an operating tool. There are two types of measuring devices for liquid steel temperature measurements available; one uses a noble metal thermocouple consisting of platinum-platinum rhodium wire; the other utilizes a radiation unit or blow tube. Both of these units require specialized maintenance from the instrument service department, particularly the recording instrument, which is of the high speed electronic type. Our experience has been limited to the thermocouple type instrument, using a thermocouple assembly illustrated in Fig. 5. In all installations of this type, the design of the thermocouple is of primary importance both from a maintenance viewpoint, and the cost of the

THE AUTHOR

Educated in Canada, Mr. Cuthbert received his electrical experience with the Winnipeg Electric Railway System. In 1923 he joined the Illinois Steel Corporation (now Carnegie Illinois Steel Corp.) as a sub-station operator, and was transferred to the Instrument Group in 1926. He graduated from Fort Wayne School of Meter Engineering in 1933 and was placed in charge of the South Works Electric Meter Department. In 1940 he took charge of the combined instrument groups as Supervisor of Instruments and Controls.

*Carnegie Illinois Steel Corp., South Works, Chicago, Ill.

NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y., Sept. 12-18, 1950.

Statements and opinions expressed in these articles are those of the author and not necessarily those of the Society.

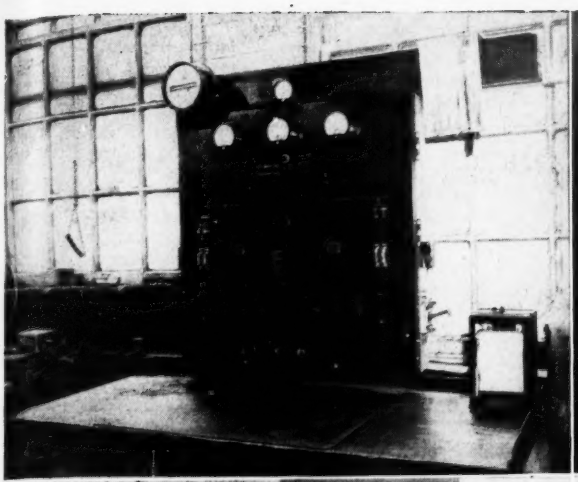


Fig. 1 (Top)

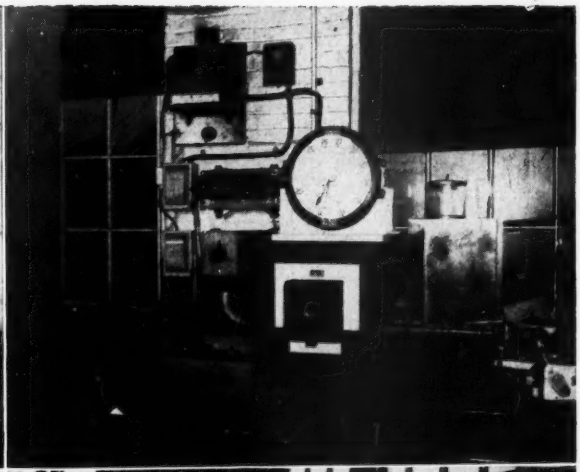


Fig. 2 (Top)

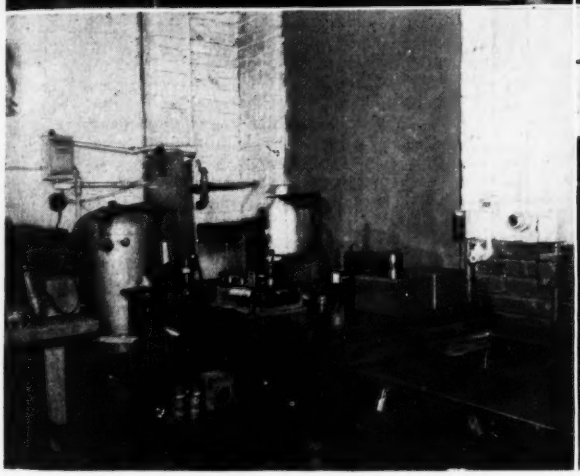


Fig. 3 (Bottom)

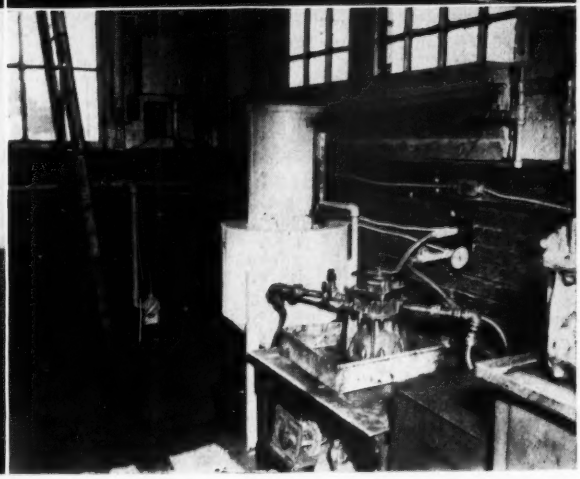


Fig. 4 (Bottom)

assembly. One of the major problems encountered is the heat gradient at the head of the assembly; in most cases it is necessary to place the cold junction far enough back to eliminate any errors due to overheating of the compensating lead wire.

We have conducted some experiments on the noble metal compensating lead wire to determine the feasibility of extending this lead wire to within six inches of the hot junction in taking bath temperature measurement. From previous experimentation it has been concluded that the temperature at the junction of the platinum-rhodium thermocouple with the compensating lead wire does not exceed 200 to 300° F. while the actual bath temperature is being measured. It was also concluded that after the reading has been taken and the measuring device removed from the furnace, the temperature at the junction increased to a maximum of approximately 1000° F. It was therefore necessary to test the compensating lead wires to ascertain the effect of the junction temperature upon the accuracy of the thermocouple and also to determine if the lead wire was affected in any way by being subjected to high temperatures after taking the measurement of the bath temperature.

A thermocouple was made, using the compensating lead wire normally used to connect platinum-platinum rhodium thermocouples to the measuring device. This couple was then inserted into a small electric furnace, heated to increasingly greater temperatures, then allowed to cool. A study of Fig. 6 will reveal that the thermal characteristics of the wire apparently affected very little.

Another complicated installation and maintenance problem in a modern open hearth results from the general use of various fuels. The device for measuring these fuels in gallons per minute, or per hour, has to be interconnected with, or be part of, a control system. The maintenance, calibration and accuracy of this equipment again falls into the responsibility scope of the instrument service department.

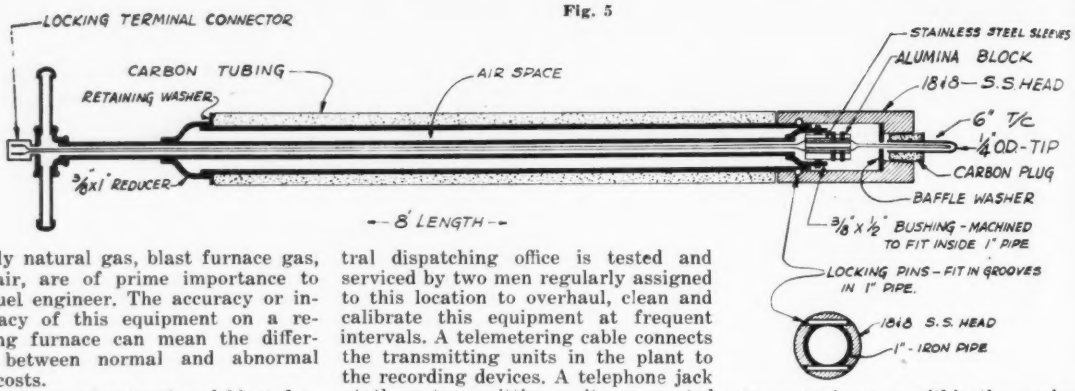
In setting up a test unit to calibrate positive displacement meters, a simple, yet effective method was devised. Fig. 7 shows clearly a practical method for calibrating this type of meter to within one half of one per cent. Two tanks are used, one of 75 gallon capacity for oil storage; the other, a 50 gallon calibrating tank, is so designed that the top section or stack will accommodate about 10 gallons. A water gauge glass (Fig. 8) is installed adjacent to this stack so that one gallon increments can be inscribed on the glass, or a scale (divided into one gallon values) can be placed alongside the glass. By pumping oil through the meter under test and comparing its readings with the number of gallons indicated on the water glass, an accurate calibration can be obtained. The aforementioned applications and problems associated with the use of instruments in the open hearth afford some idea of the development work accomplished in this field.

Other departments in a steel producing plant are confronted with similar problems. Calibration of radiation units, both the lens and mirror type, is a major responsibility. These radiation units are used in taking soaking pit temperature measurements, blast furnace stove dome temperatures, and for rolling temperatures. Some of the steel plants use base and noble metal thermocouples for this purpose; however, our experience has shown a lower maintenance cost in the use of radiation tubes over the use of thermocouples.

Maintenance of this type equipment in the field requires competent and well trained journeymen who understand the proper use of an optical pyrometer in making calibrations.

The rolling mill reheating furnaces are equipped with temperature recorders and controllers, fuel ratio controls, and furnace pressure controls. Flow indicators showing the amount of fuel,

Fig. 5



usually natural gas, blast furnace gas, and air, are of prime importance to the fuel engineer. The accuracy or inaccuracy of this equipment on a reheating furnace can mean the difference between normal and abnormal fuel costs.

In the use of natural and blast furnace gas throughout the plant, the orifice type flow meter is used extensively for measurement of these fuels. In both open hearths an individual flow meter is used to measure the gas used in each of the 28 furnaces. A main meter is located on the gas main entering the building. All of these meters are read every 24 hours and to obtain a balance of 14 different readings to one totalizer has been a problem of long standing.

To derive close tolerance between our totalizers and furnace meters, it is necessary to conduct frequent calibration tests. In the plant are four meters that measure approximately 80 per cent of the total natural gas consumption. These meters are tested on a bi-weekly schedule; other meters used on natural gas are tested monthly or bi-monthly, depending on the importance of the installation.

Blast furnace gas is perhaps the most difficult of all fuels on which to obtain accurate flow measurements. Most of the present day metering equipment will perform satisfactorily; however, the orifice plate located in a blast furnace gas main receives so much abuse from water and sludge that the accuracy of a flow meter is seriously affected. At some locations in the plant, the mains as well as the orifice plate receive a weekly flushing with live steam.

In recent years, central dispatching offices have been established in the larger plants for controlling the usage and amount of power, fuels and steam required by the operating units. The panel boards for load and fuel dispatchers usually consist of various types of instruments that indicate and record steam, gas and power being manufactured and used at predetermined points in the plant. The steam control board is equipped with flow recorders capable of indicating steam production at distances up to a mile from the dispatching office. The blast furnace and natural gas board is equipped with flow and pressure recorders indicating the gas pressures and amount of fuel being used in distant locations throughout the plant. The electric panel records and integrates both the power output of the generating stations and the power actually consumed by plant equipment. Included is an instrument that records the power exchange over a 66,000 volt line connecting South Works and Gary Works (a distance of 20 miles).

The metering installation in the central dispatching office is tested and serviced by two men regularly assigned to this location to overhaul, clean and calibrate this equipment at frequent intervals. A telemetering cable connects the transmitting units in the plant to the recording devices. A telephone jack at these transmitting units, connected to one telephone jack in the dispatching office, is provided for use by the instrument men.

Several hundred control units are maintained by the Instrument Department. The majority of these controls are hydraulically operated and must be maintained in efficient working order to effect real economy in steel production.

In general, two systems are employed in most instrument maintenance work. Some plants control and direct all their maintenance from one central point while others may use two or more specialized groups who confine their activities to one department, or perhaps to one general class of equipment. The concensus leans toward the use of one central instrument maintenance group, where the aptitude and training of personnel can be extended into combinations of instrument work.

It has been demonstrated that an efficient instrument maintenance department should not attempt to rely solely upon personnel working within the department to insure proper handling and operation of costly and fragile instruments. For this reason every opportunity is utilized to advise, caution or demonstrate to operators in the control rooms within the producing units the function of this equipment so they will have a thorough knowledge of its scope and limitations.

The total personnel required to efficiently handle a well-coordinated instrument and control maintenance program has been the subject of frequent controversy over a period of years. This condition is dependent largely upon the number of instruments assigned to each serviceman, the importance of the instruments and the process involved, rather than delineation by types or manufacturer. In our plant, the servicemen are assigned to specific areas regardless of the number of instruments operating in each area. These men remain on their particular assignment until they become thoroughly versed in all minute details of the equipment maintained and the process being measured and controlled. Also, under this arrangement they develop a mutual acquaintanceship with the operating personnel, and gain an intimate knowledge of plant physical lay-out enabling them to reach locations of breakdowns or emergency conditions without delay. This combination of experience reduces and minimizes outage time on replacement of equipment.

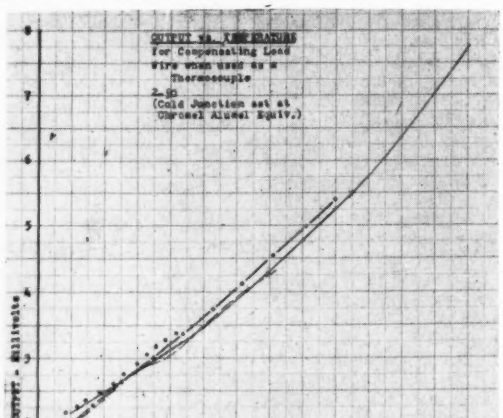

Thermocouple
(Cold Junction set at
Chromel Alumel Equiv.)
CODE:
Data - Initial Run Cooling from
518° Fahrenheit
Dashes - Run 2 Cooling from 800 °F
Dot Dash - Run 3 Cooling from 1030 °F
Solid - Run 4 Cooling from 1400 °F
TEMPERATURE - Degrees Fahrenheit

Fig. 6.

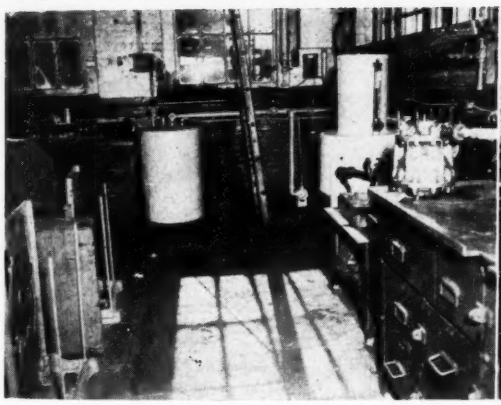


Fig. 7.

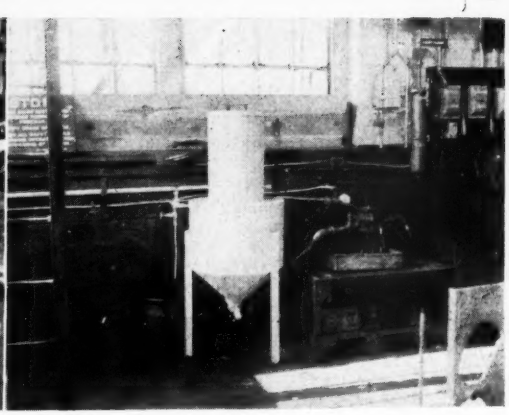


Fig. 8.

The number of men assigned to the operating units ranges from two to five, the figure being governed by the area involved. In these various groups, top rate journeymen are responsible for the general conduct and productiveness of the men as well as the condition and accuracy of the equipment being maintained. A gang leader in the field supervises all activities and participates in the work whenever and wherever it is necessary to expedite any particular phase of the project.

In the Meter Laboratory another gang leader assigns and supervises all shop work, handles incoming trouble calls, checks material and prepares orders for both store and special order materials and equipment.

We have found it very expedient to have all personnel report to the laboratory in the morning before proceeding to their respective areas or work location and repeat this action shortly before quitting time. This arrangement affords the group an opportunity to discuss the many problems entailed in this type of work and possibly evolve satisfactory solutions. We believe these discussions not only create a congenial relationship between the men but also provide increased maintenance experience and improved job methods.

This plant does not enter into any service contracts with instrument manufacturers except on sealed thermal elements, such as the mercury or gas filled systems. This equipment requires expensive calibrating apparatus, purchase of which is not warranted since we have few of these units in use. We do, however, utilize the manufacturer's consulting service on technical problems and on occasion invite a field engineer to present a paper or discussion of approximately two hours duration to our field personnel.

A complete catalog file is maintained on all types of meters and instruments, controls and related supplies in order that pertinent information will be available to all concerned. Technical books are also provided for employee's use by both the laboratory and the plant library.

CONCLUSION

In this paper I have attempted to outline the salient points of an instrument department's activities in a large steel plant. From the facts presented it seems reasonable to conclude that instrument and control maintenance is justified and the instrument repairman's job includes many problems to solve. We sincerely believe that existing and future instrument installations will increase production, and unquestionably, modern instrumentation has made it possible to study and improve furnace operation and efficiency.

One Knob Production Control

By C. F. ADESZKO *

Abstract. The degree of simplification that has been attained for the industrial process through the application of instruments, such as the ability to regulate total plant capacity from a single control device, is first discussed in a general manner. A case history which deals with a batch-type corn syrup refinery is used to illustrate the method for engineering a one-knob production control system. Detailed consideration is given to the special circuits and interlocks which are characteristic of this type of control application work. The paper is concluded with facts which point out the economic advantages that are realized by the large scale application of instruments and controls.

I. Introduction

It is a recognizable fact that the most influential device of the present era is the television receiver, which is making its entry into more homes each day. Since it was first generally introduced, this unit has been under continual development to improve on the results that were being obtained, and to simplify the method of operation in the home. Undoubtedly the most significant advance that has been made is the degree of simplification that has been attained in the operating techniques which the average owner must have in order to get good results with his set. In the early days of its general usage, the complicated procedure for picture tuning, left much to be desired in the way of television reception. The receiver has now been improved to the point where picture tuning can be accomplished with very few adjustments. As a matter of fact, certain sets are advertised to be capable of "single knob tuning" or "single knob picture control."

Similarly, in the industrial world the production process has realized much development. This has been greatly due to a widespread use of instruments and automatic controls which have been applied to coordinate unit process operations. In most cases the application of these devices has made it possible to reduce in great degree the complexity of operating techniques required by complete manual operation. This is especially true of the batch type process which by virtue of its network of independent unit operations, requires a large number of operators in order to realize production results. The application of instruments and automatic controls provides a much simpler method for directing these operations to a desired production schedule.

There is no question of the fact that the application of control equipment has tended to reduce the need for the large number of operators that are usually required for complete manual operation of a batch process. The large number of manual manipulations have been replaced by a decidedly lesser

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Mr. Adeszko received his engineering training at Armour Institute of Technology in Chicago, and his BS degree in Chemical Engineering in 1939. His work with various chemical concerns led to a position in 1942 with the U. S. Rubber Company of Mishawaka, Indiana, where he engaged in instrument application work in the production of special war products. In 1945 he joined the control application group of the Chemical Division at Argo, which later was transferred to the Chemical Engineering Department of Corn Products Refining Company at Chicago.

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number of instrument settings, in order to obtain equivalent production results. By virtue of subsequent engineering developments in the control application field, it has been possible to realize the same degree of simplification in operating the instrumented industrial process as the television receiver in your home. In likeness to "one knob picture tuning" we have realized one knob production control for the industrial process.

The case history which provided the material for this paper, namely, the corn syrup refinery of the company's Kansas City Plant, is an existing example of this development. The process was instrumented in sufficient degree to accomplish the flow of materials almost entirely automatically. The unique feature of the instrumentation that was applied is the ability to change the production rate or daily plant output by merely adjusting "one control knob."

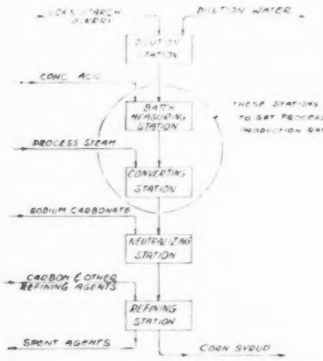


Fig. 1. Block Flow Diagram of Syrup Making Process.

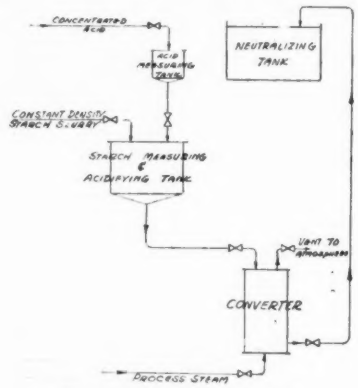


Fig. 2. Flow Diagram for a Batch Converter.

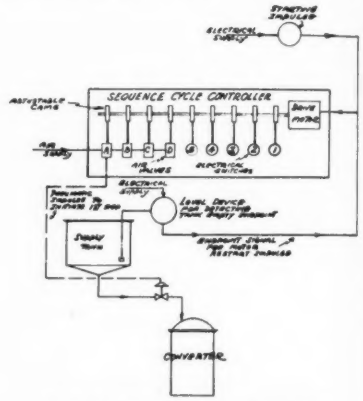


Fig. 3. Operation of a Sequence Cycle Controller.

II. The Process

The advantages to be gained by instrumenting a process in the manner discussed cannot be appreciated without first considering a method of complete manual operation. The basic method for making corn syrup from corn starch is shown in the block flow diagram illustrated in Fig. 1.

Briefly, such a process consists of several batch operated stations which are independent of each other. Each station requires the attention of one or more operators to execute the processing steps that are characteristic of that station. The starch for conversion to syrup comes to the process in a slurry form. This must be diluted to a pre-determined gravity before conversion. The diluted slurry is then measured by means of tanks in volumes determined by the capacity of the converter vessels. The slurry is also acidified with a measured quantity of acid at this station. The converting station consists of several batch reactors or converters, in which the controlled application of heat in the form of live steam effects the conversion of the acidified starch to syrup. The number of converters used and duration of the converting cycle determines the maximum production capacity for the entire process. The syrup is then neutralized to remove the excess acid. The remainder of the process consists of several refining operations which produce the saleable product.

The manual operation of a plant of this type presents many problems which must be overcome in order to realize profitable results. First, there is considerable difficulty in coordinating the efforts of the operators at the various stations because of the inherent independence which exists between them. For example, uniform operation of the converter station requires that starch is always available at constant gravity. Interruptions in the operation of the dilution station might not become known to the converter operators in time to adjust their converting schedule to a new rate, and this can result in several batches to be made with incomplete charges of starch. If the acid added is not proportionately decreased immediately, non-uniformity of the product will result. This represents increased operating costs due to the subsequent reprocessing which becomes necessary. Another example, is the effect of irregular converter operation on the neutralizer station. The inability to synchronize the operation of the converter station with that of the neutralizing station causes fluctuations in the supply to the various refining operations. This reduces the operating efficiency which is maintained at these subsequent stations. Another problem is caused by the inability to provide sufficient steam supply capacity for handling the various demand requirements which inevitably occur when the converting rates are frequently changed. This is especially noticeable when the rates are suddenly increased. This problem is doubly serious since it affects boiler house efficiency as well as product uniformity.

From the history of the original plant, several shortcomings were manifested in the manual method of operation which greatly influenced the productive capacity for this process. The inability of the plant to continuously maintain the maximum production capacities for which it was designed was attributed in great proportion to the operating losses which were incurred. The major causes for these losses were: (1.) Operating errors in executing batch cycles, (2.) Non-uniformity of executing successive batch cycles due to the inability of operators to maintain the standards that were required, and (3.) Lack of coordination between processing stations. The above factors were responsible for the inefficient utilization of plant utilities and services such as steam, water, compressed air, electrical power, etc., and also the excessive use of raw materials, all of which increased the operating costs for this process.

As was previously mentioned, the production capacity of the entire process is dependent on the rate of operation which is maintained at the converter station. This can well be termed the "heartbeat" for this process, since it provides a convenient means for throttling its output. For an example, if the supply of raw materials is interrupted for any reason, the converting rate can be slowed down sufficiently to maintain operation until the normal supply rate is restored. Likewise, if process breakdowns occur at points which follow the converting station, the converting rate can be reduced to maintain a slower schedule until the condition is corrected.

The operation of a typical batch converter is illustrated in Fig. 2. The batch converter is merely a retort usually of approximately 3,000 gallons capacity. Connections are provided for injecting the acidified starch at the top. The starch slurry is measured in an overhead tank and acid is added to the slurry from a separate measuring tank. With the neutralizer discharge valve closed and the vent valve open, process steam is introduced in a counter-current direction to the injected starch to assure adequate contact for heat transfer. The operator must manually throttle the steam inlet valve to maintain a slight positive pressure during this portion of the cycle. When all of the starch is passed into the converter, the starch inlet and vent valves are closed, the pressure in the converter is raised with live steam to the value which gives the desired temperature for the conversion. The batch is held for a predetermined interval of time at this temperature to permit the reaction to go to completion. The discharge valve is then opened and the converter contents are forced into the overhead neutralizer by means of the pressure in the converter.

The operation of a converter as described appears straightforward and not too difficult for manual operation. However, the amount of valve manipulation and operating attention required imposes a maximum "converter to operator" ratio of 2 to 1. The chemistry

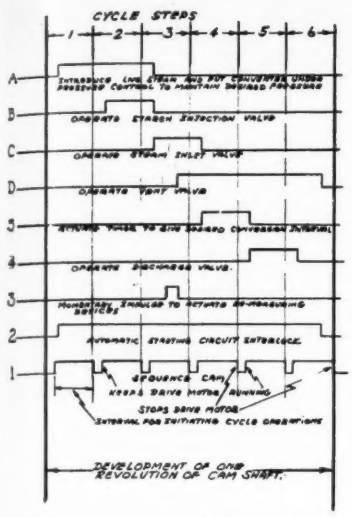


Fig. 4. Sequence Chart for a Typical Converter Cycle.

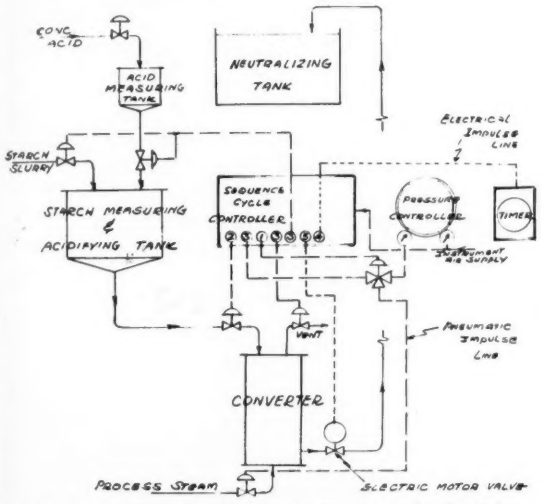


Fig. 5. Schematic Layout for Automatic Cycle Control.

of the conversion reaction requires that the variables of steam rate during starch injection, converting temperature, and time of reaction be watched rather closely in order to realize a consistent product. The limitations of human endurance and susceptibility of human nature to deviate from routine procedure presents the natural causes for failure to meet the standards of reproducibility needed for maintaining product quality in a batch operation of this type.

Several examples can be presented to illustrate the responsibility of the operator who attends this process.

(1.) The failure to add acid to the starch which has been charged into the converter results in a charred mass which represents a total loss in raw material. This amounts to 3,000 gallons of slurry of a high quality starch.

(2.) Another instance, is the failure of the converter operators to schedule batches so as to avoid the excessive draw of steam required by more than two converters in simultaneous operation. This mistake results in a severe load on the boiler house, and many times leaves the attending fireman in a serious debate as to whether he should take a gauge reading or the nearest exit for safety from a boiler that appears to be leaving its foundation.

(3.) A third example of operator responsibility is important because of the hazardous possibilities which can result between misunderstandings in instructions between the converter and neutralizer stations. Discharging the contents of a converter into a neutralizer which is not ready for a full batch can cause serious accidents when one considers the elevated temperature of processed liquor, normally 300 to 350° F.

In spite of the various difficulties and hazards attached to the operation of a plant of this type, it performed satisfactorily without recourse to instrumentation except in very limited quantities. This was primarily due to the fact that the plant was built during an era when the science of instrumentation and its application was just beginning to find its place in industry. Therefore, when most of the equipment had reached the obsolescent stage, the company realized a good opportunity to fully modernize this process by replacing the old equipment with that of most recent design and incorporating refinements in operating techniques such as could be provided by complete instrumentation.

The incorporation of instrumentation was made even more attractive after considering the capital investment that would be involved for another manual process as compared with an instrumented process. With manual operation, seven converter units would be required to obtain the desired maximum production capacity. The preliminary engineering considerations indicated that the application of instrumentation to accomplish automatic operation and scheduling of the converter station would permit cutting the number of converters by one. It also appeared that the capital investment for this one converter and its related equipment would approximately equal the cost of the instrumentation for this entire station.

III. The Application Of Control Instruments

The engineering needed to lay out the instrumentation for an automatic production control system begins with an analysis of the unit batch operation involved, in this case the operation of the converter, the batch measuring tanks, and the neutralizers. The execution of the various steps of a complete converting cycle in a definite order, requires the use of a sequence-type cycle controller. The cycle controller which is illustrated in Fig. 3 consists of a combination of air pilots and electrical switches which are actuated by means of adjustable cams driven from a common cam shaft. The time as selected for one revolution of this shaft is slow enough to permit spacing of the actuating cams with a sufficient time interval for each sequence, to assure proper operation of the control and interlocking devices for each cycle step. Therefore, when the drive motor is started, either manually or automatically, the controller initiates the first step in the cycle and then stops again. In the example shown, air pilots "A" applies air to the diaphragm of the valve between the supply tank and the converter, permitting the contents of the tank to empty into the converter. The controller then remains dormant until the first step of the cycle is completed. The completion of a step or portion of the cycle is usually manifested by a signal from a control device or devices located in a manner which permits the device to detect the endpoint for that particular cycle step or operation. In this case a level device indicating that the tank is empty provides this signal. The control device by means of various control

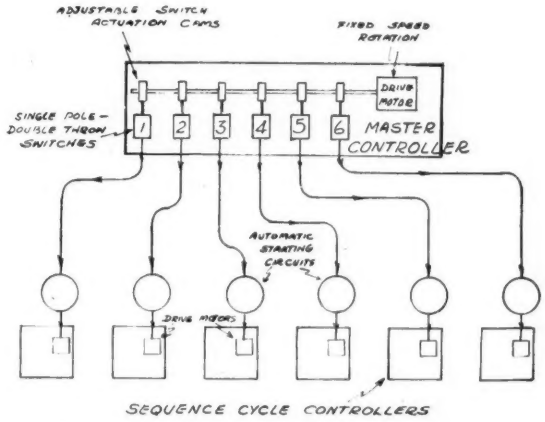


Fig. 6. Schematic Diagram for Master Controller.

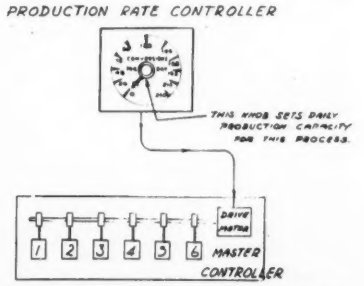


Fig. 7. One-Knob Production Controller.

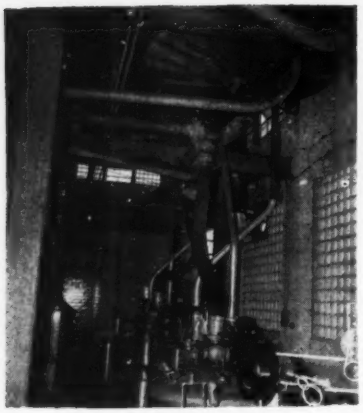


Fig. 8. Process Equipment.

interlocks, relays the completion of this step back to the cycle controller drive motor restarting it. The controller then restores the air pilots or switches of the previous step and actuates the pilots or switches which initiate the next step in the cycle. The cycle progresses in this start-stop manner until the entire cycle has been executed and then remains at rest until it receives the next starting impulse.

The sequence development chart shown in Fig. 4 is very helpful when laying out sequence control systems of this type. The development of a complete cycle for one revolution of the cam shaft appears on this chart. For this particular process, the capital letters indicate the air pilot valves that are used for the pneumatic actuations required and the numbers refer to the switches used for electrical impulses and interlocks. Cam No. 1, of course, is the sequence cam which stops the drive motor after each step is executed. The raised portion of each line indicates in which step the air pilot or switch is actuated and restored. The use of this chart becomes apparent after considering at least one cycle step. Assume that a starting impulse is received and the drive motor starts. The cam shaft rotates and cam No. 1 is actuated. The electrical switch keeps the drive motor running independent of its starting impulse. Switch No. 2 is actuated deenergizing the starting circuit. Air pilot "A" actuates control devices which put the converter on

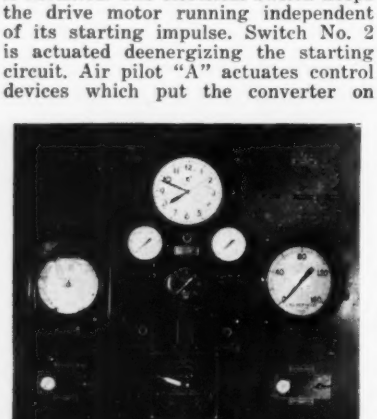


Fig. 11. Master Control Panel with Rate Controller — Front View .

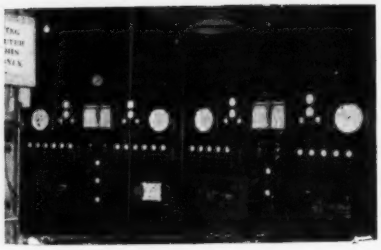


Fig. 9. Sequence Control Panel for Two Converters — Front View.

automatic steam pressure control. Switch No. 1 opens again and the drive motor stops. The pressure in the converter is brought to a predetermined value at which time a pressure switch in series with the drive motor, starts it and the cycle is now in Step No. 2. The remaining steps are executed in a similar manner.

Having applied the sequence controller and related control equipment for automatic operation of a converter unit, the original diagram of a converter process shown previously in Fig. 2 now takes the form shown in Fig. 5. This, of course, is purely schematic, but it serves to indicate that the manual operations are now executed entirely automatically.

The impulses from the sequence controller are numbered in the order of their occurence. The manual valves are replaced by diaphragm operated control valves with the exception of the discharge valve, which is an electrically operated valve. An electrical timer is used to give the desired holding time for the reaction period. A pneumatic pressure controller operates automatically during the starch injection period, to maintain the desired value of positive pressure in the converter.

The special circuits and control interlocks for arranging the sequence of operation of the cycle controller are not as simple as the diagram shown might suggest. Since the consideration of these is beyond the scope of a presentation of this type, examples of these are covered in the appendix.

The advantages that become immediately apparent by the instrumentation applied thus far are: (1.) Accurate measurement of raw materials, (2.) Uniform steam pressure control during starch injection, and (3.) Accurate holding time duration.

The next phase of control application is concerned with the method of automatic scheduling of the batch converters. It is apparent that scheduling in any form would not be effective unless the batch operations were consistently reproducible. This is assured by the use of the sequence controller previously described.

For automatic scheduling of several converters a master controller is used. The application of such an instrument is illustrated in Fig. 6. As shown, the controller consists of six cam operated electrical switches having a common cam shaft. Each switch is wired into a separate starting circuit, which automatically initiates the starting of a sequence cycle controller for a batch converter. The actual electrical circuits for accomplishing automatic starting are covered in detailed diagrams included in the appendix.

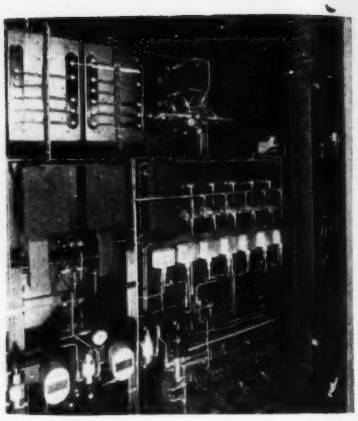


Fig. 10. Sequence Control Panel for Two Converters — Rear View.

The sequence of operation of the switches in the master controller can be arranged in any desired pattern by means of the adjustable cam operators which are driven from the common cam shaft. The speed of rotation of this cam shaft then determines the output of the converter station, since each batch converter is put into operation once for every revolution of the cam shaft. It is apparent then that the minimum revolution time which this shaft can have, is the maximum time that is required for a complete cycle in any of the converters.

The master controller, depending on the speed of rotation of its drive motor, sets the maximum production capacity for this process. The application of this unit makes it possible to realize additional operating advantages, namely: (1.) Coordination of operation between three stations, the batch measuring station, the converter station, and the neutralizer station, (2.) Levels out the utilization of plant services, particularly process steam. This is reflected as an improvement in boiler house operation, (3.) Smooths out the delivery of product to subsequent unit operations, and (4.) Provides the important features of production scheduling.

Very few processes are operated with the same daily production output. Market demands require some flexi-

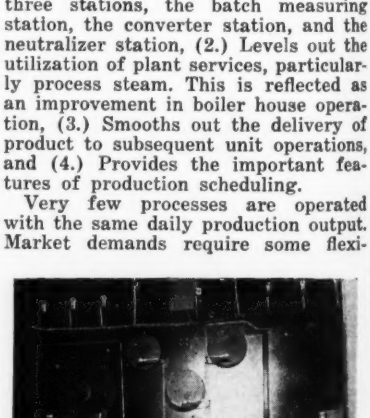


Fig. 12. Master Control Panel with Rate Controller — Rear View.

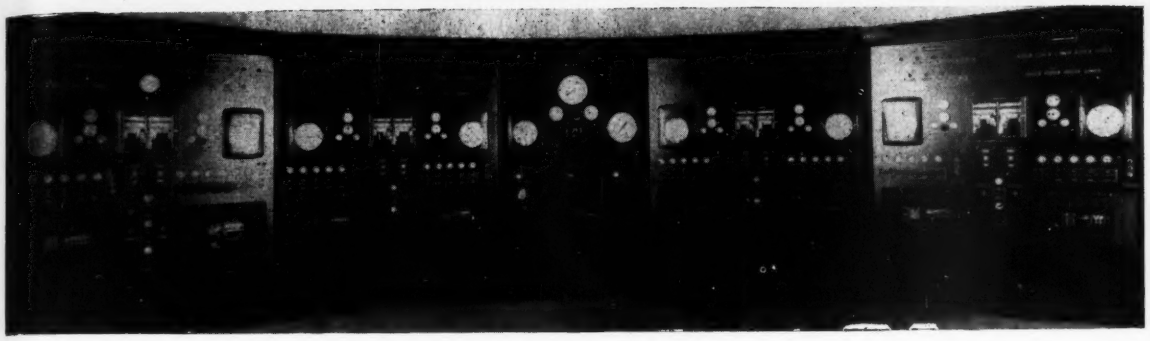


Fig. 13. Complete Control Panel.

bility in daily production rates. This feature makes necessary the next and final phase of this process control system. As illustrated in the last sketch, Fig. 7, the final element in the production control system is the rate controller.

The rate controller is a percentage timer or calibrated interrupter, which consists of a motor and an electrical contact which is mechanically actuated for each revolution of the motor. The contact in the timer can be set to remain in a closed or open position for any time interval from 0 to 100 per cent of the rotation time of this motor. The motor usually makes one revolution per minute.

The drive motor of the master controller as previously mentioned, has a fixed speed of rotation. The rate controller provides a means to vary this speed over a definite range by means of power interruptions to this drive motor. The electrical circuits for this feature are shown in more detail in the appendix.

The dial for a percentage timer is normally graduated in percentage numbers of 0 to 100. When employed as a rate controller for a production process this can be changed to number of batch operations per day required for a definite production output. In this case, for example, the graduations are in conversions per day.

The setting of this rate controller in effect, realizes the unique feature of this process control system, that is, the ability to set daily production output for this process by merely setting "one control knob." The process output to meet any market demand within the range of the equipment processing capacities, is readily adjustable by no more than a finger-tip operation.

The attached pictures, Figs. 8, 9, 10, 11, 12, 13, 14, are intended to give the reader some idea of the physical proportions of an installation of this type.

IV. Demonstrated Results

The merits of a production control such as was just presented can be evaluated in several ways. However, there is one opinion that was advanced in behalf of this project which defines its accomplishment very well, and which stresses one of the foremost benefits that is derived from the application of a coordinated control system to several batch units.

The opinion was voiced by one of the process group who actually grew up in the old manually operated process. When asked for his comments after the process was in operation for several months, he likened the instrumented batch converters to hens that were in the process of egg laying. "It's the darndest thing I ever saw, every twelve minutes one of those converters starts to lay an egg, and each new egg is like the last one."

Actually, however, the results that were realized after several months of operation can be more specifically presented.

(1.) The use of one man to oversee the control station is the extent of operator attention required after the process was instrumented. This represents a reduction in operating manpower of three men per shift based on the previously mentioned requirements for the manually operated process having seven converter units.

(2.) The improvement resulting from increased processing uniformity, namely, that gained by measurement of raw materials and reproducibility of the batch operation through automatic sequence control was reflected 4 ways:

(a) Increased yield in pounds of dry substance of the final product. This can be considered as a monetary gain either from the standpoint of the savings due to reduced quantities of starch used to produce a desired amount of syrup, or as additional earnings due to increased saleable product.

(b) Reduction in the use of raw materials, of which the acid required for conversion is a specific example.

(c) Reduction of reprocessing requirements resulting from elimination of operating errors and tank spillages.

(d) Reduction of total product losses.

(3.) The decreased operating costs resulting from automatic scheduling of the batch units were reflected as:

(a) Uniform steam draw from the boiler house which improved efficiency of the steam generating equipment.

(b) Decreased consumption of steam due to controlled steam utilization during the process.

(4.) Process flexibility resulted in competitive advantages which were reflected as:

(a) Ability to revise process procedures to meet varying product specifications.

(b) Ability to process special products for expanding market applications.

(5.) Improvement in employee-employer relations resulting from:

(a) General improvement in process environment and working conditions provided by the modernization of the process. Ease of operation, cleanliness and adequate protection from hazardous conditions had a marked effect on the morale of the process group.

(b) Improvement in the operator's job outlook realized on the basis of higher standards of individual initiative and ability.

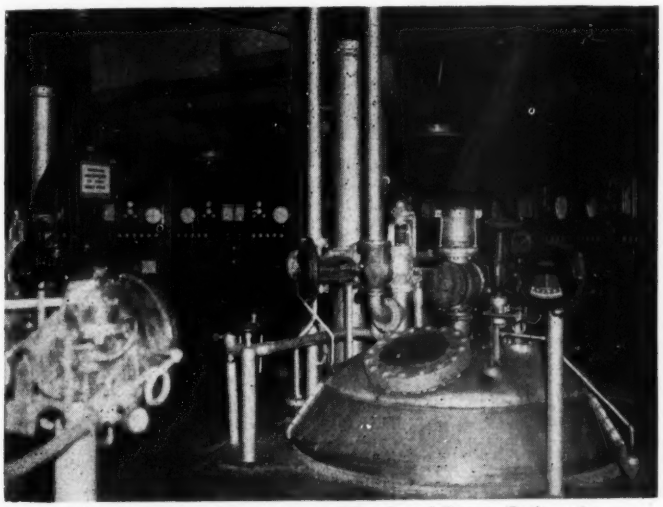


Fig. 14. Composite View of Control Panels and Process Equipment.

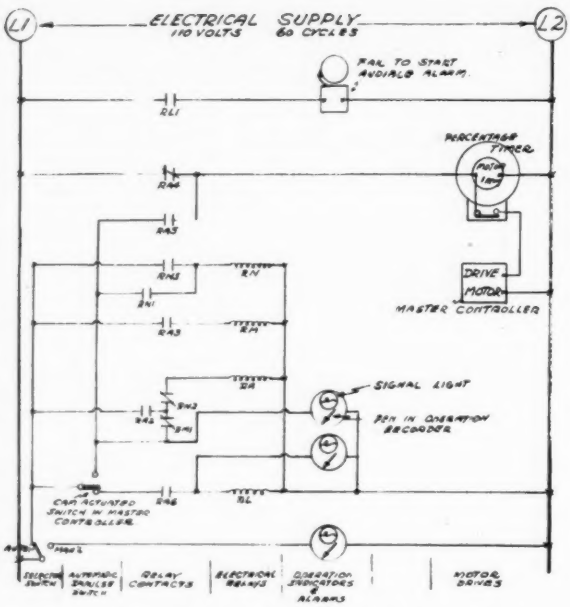


Fig. 15. Circuit Diagram for Automatic Starting Impulse.

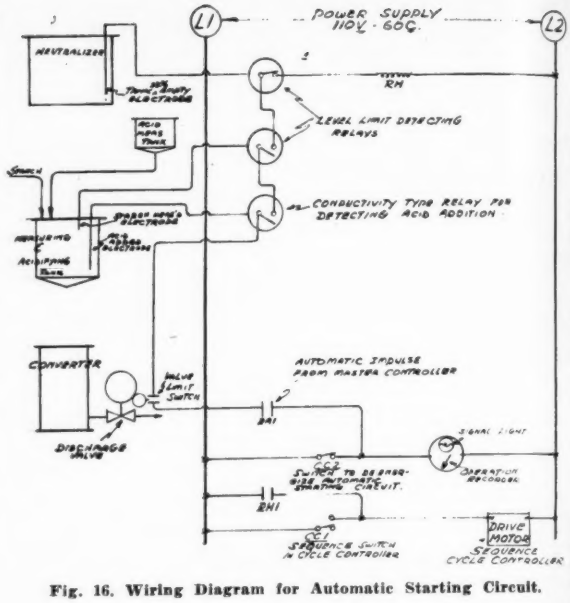


Fig. 16. Wiring Diagram for Automatic Starting Circuit.

Conclusion

One knob production control is designed to provide the following features for a multiple unit batch type process:

(1.) Automatic sequence control for each unit.
(2.) Automatic scheduling of all the units.
(3.) Automatic rate control for setting daily output from the total number of units.

The example that was used to illustrate the method for applying such a control system is specific for the corn syrup production process. However, the similarity between the manual operations required for this process and those which characterize other batch type processes might possibly suggest new applications for the principles that are covered in this paper.

Appendix

The wiring diagrams for the basic control circuits usually applied to coordinated control systems have been appended for the readers reference. These have been prepared as the ladder type diagram to facilitate their reading. The diagrams serve to illustrate these functional applications:

(1.) Method of providing the automatic impulse from a master controller to start a sequence cycle controller. This diagram also illustrates the wiring of the percentage timer in its use as a production rate controller.
(2.) Operation of the starting circuit with respect to process limitations.
(3.) Typical sequence circuit illustrating the method for interlocking electrical signals with pneumatic impulses.

Each diagram is individually explained.

1. Automatic Momentary Impulse for Starting the Sequence Controller Fig. 15

The selector station must be in the automatic position. In the original position contact RA4 is closed so that power is on the synchronous motor of the percentage timer. The switch in this timer furnishes power to the drive motor of the master controller. The actual rotation of the drive motor is dependent on the setting of the percentage timer which interrupts the power to the drive motor for a fraction of each minute.

The drive motor rotates the cam shaft and the switch indicated is actuated to the upper position at some point in the rotation of the shaft. Relay RA is energized which actuates all the contacts of this relay.

Contact RA2 holds-in the starting impulse independent of the cam actuated switch, which is opened a short time later.

Contact RA3 energizes relay RM. This opens contact RM1 which deactivates the controller impulse immediately, giving the equivalent of a manual momentary contact.

Contact RA1 which appears in the succeeding diagram, Fig. 16, is closed. If the sequence cycle controller starts, as will be explained in the next diagram, a response signal indicating the start has been accomplished, is made when contact RH3 closes energizing relay RN. Contact RN2 then deenergizes start relay RA.

If the sequence cycle controller fails to start, the cam actuated switch is again restored to the lower position. Contact RA6 would then energize relay RL. Contact RL1 closes to sound audible alarm, indicating this condition.

Contacts RA4 and RA5 stop the synchronous motor of the percentage timer until the cause for failure to start has been determined.

2. Operation of the Starting Circuit Fig. 16

This diagram illustrates the circuits which are interlocked electrically with the starting impulse to comprise the starting circuit for the sequence controller. For complete automatic operation, the starting of a batch converter is dependent on its ability to carry out a cycle to its completion. Therefore, it is necessary that several conditions are satisfied at the time the starting impulse is given.

In this example, the starting circuit consists of four other contacts in series with contact RA1, which must be closed for the starting circuit to be effective.

A. First, the discharge valve must have closed itself from the previous cycle. An integral limit switch verifies this condition.
B. Second, a measured charge of starch must be available. The level in the measuring tank is measured by means of an electrode type level relay. The contact integral with this relay must be closed.
C. Third, the measured charge of starch must have been acidified. The conductivity of the resulting solution is used to actuate a relay, which has an integral contact also in the starting circuit.
D. Lastly, the previous batch in the corresponding neutralizer must have

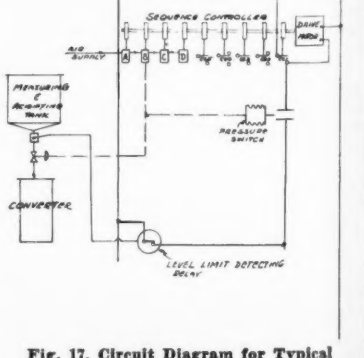


Fig. 17. Circuit Diagram for Typical Sequence Interlock.

been advanced so that not more than 25 per cent is left when the next cycle is ready to start. A similar level relay verifies this condition.

With all of the above contacts closed, the starting circuit is completed, which energizes relay RH. Contact RH1 closes, starting the drive motor of the sequence controller. The cycle controller immediately sustains itself independent of the starting circuit by means of the cam actuated switch CC1, which is closed. From this point, the sequence controller initiates the various cycle events in the sequence shown in Fig. 4, by means of sequence control circuits as illustrated in the next diagram, Fig. 17. Contact CC2 is opened to deenergize the starting circuit a moment after CC1 is closed.

3. Typical Sequence Interlock Fig. 17

Having started the drive motor for the sequence controller, various cycle operations are automatically carried out as illustrated in this diagram. Cam operated switch CC1 is closed as indicated previously and assume air pilot "B" is actuated by its cam in the sequence illustrated in Fig. 4. Air is applied to the diaphragm of the starch inlet valve, permitting the contents of the tank to be emptied into the converter. Switch CC1 is opened then and the drive motor stops.

The same air impulse is used to actuate the pressure switch shown, closing its contact. This contact is in series with the contact in the level relay, which is in the open position when there is liquor in the measuring tank. As soon as this tank is emptied, the level contact is closed, completing the circuit to the drive motor once more. Contact CC1 closes to sustain the drive motor and pilot valve B is restored. The succeeding cycle step is initiated by actuating the next cam operated element, air pilot or switch. The entire cycle is executed automatically by similar start stop operation of the sequence controller.

A Mass Spectrometer for Monitoring Continuous Processes

By CHARLES F. ROBINSON, HAROLD W. WASHBURN, CLIFFORD E. BERRY and GEORGE D. PERKINS *

ABSTRACT. A mass spectrometer developed specifically for industrial process monitoring is described. The instrument is sharply different from analytical instruments in that it records only a limited number of preselected mass peaks, and in that the instrument periodically standardizes itself against a sample of known composition in such a way that the three selected peaks are automatically brought to predetermined levels on this standard sample. The three peaks may be recorded at widely different sensitivities if desired. Record presentation is such that even an untrained operator is immediately warned of instrument malfunction should it occur. The instrument is equipped with a vapor-tight pressurized case and with adequate interlocks to protect the instrument against various failures. Maintenance requirements are moderate and the instrument has been very successful in preliminary tests.

INTRODUCTION

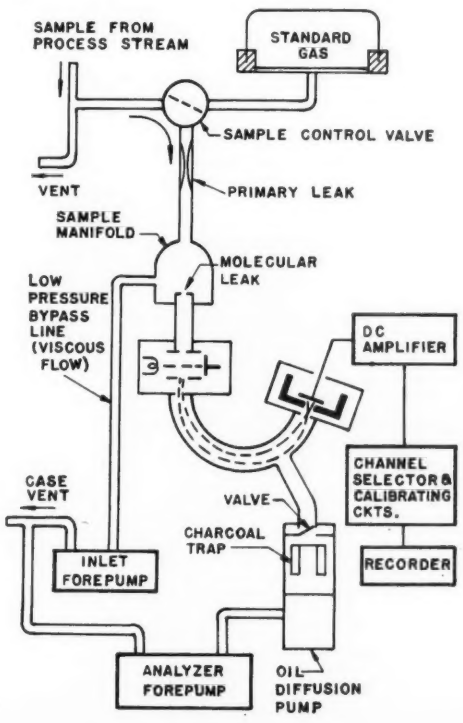
The mass spectrometer has gained wide acceptance during the last ten years as an analytical tool whose speed and accuracy in many applications are unsurpassed.[1]

Analytical instruments which have been available commercially have, however, been expensive, complex, and so needful of human understanding generally, that it is only under extraordinary circumstances, as in the atomic energy program[2], that it has been reasonable to adapt them to the routine monitoring of a continuous industrial process. More recently, however, it has appeared that there are processes in some of the chemical industries where the increased accuracy of mass spectrometer control is more than sufficient to justify the expense of an instrument designed from the outset with both the technology and the economics of the situation in mind. This paper will describe such an instrument and some of its initial applications.

There are many stringent requirements on such an instrument. The most obvious is that the sampling system must sample the process stream in an essentially continuous manner and in such a way as to respond quickly to changes in composition of the monitored stream. A second requirement is that of reliability in all of its phases. A third is that the instrument's routine operation must be at least simple, and preferably automatic, and that the information be presented in a way which can be interpreted simply and unambiguously. Still another is that the instrument must not contribute to fire or explosion hazards present in many locations, while underlying all these is the requirement that the instrument cost be held to the minimum consistent with satisfactory performance.

In addition to its continuous sampling system there are two other characteristics by which the present instrument is differentiated sharply from one designed for general analytical work. The first is that the instrument proceeds not continuously over a more or less extended region of the mass spectrum, but stepwise from one to the next of a limited number of preselected mass peaks (in the first instruments, three). Any number of mass peaks can be provided for, but the restriction of the record to the minimum number which can reveal the desired information on the monitored stream results in simplication of the record and its interpretation, in more rapid completion of any one entire scanning cycle, and in obvious cost advantages.

The second differentiating characteristic is that the instrument is auto-



GENERAL ARRANGEMENT OF MASS SPECTROMETER AND SAMPLING LINES

Fig. 1.

1. Berl, Walter G., "Physical Methods in Chemical Analysis," Academic Press, 1950.
2. Nier, A.O.C., et al. Anal. Chem., 20, 188, (1948)

*Consolidated Engineering Corp., Pasadena, Calif.

NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y., Sept. 12-18, 1950.

matically self-standardizing against a sample of constant composition. The necessity for this feature is, in a sense, inherent in the mass spectrometer method itself since one of the chief advantages of the mass spectrometer is its higher accuracy and that advantage would be largely lost by small changes in sensitivity which might be fully tolerable in another inherently less accurate but cheaper instrument. Incidental to the self-calibrating feature is the fact that each mass peak may be recorded at a sensitivity widely different from that of the remaining ones, which further simplifies the record and its interpretation.

GENERAL ARRANGEMENT

The general arrangement of the instrument is shown in Fig. 1. The monitored sample is admitted to the sample control valve through a line so proportioned as to yield the desired response time; very often a part of this sample will be by-passed around the instrument in order to maintain high flow rates and short response time. The sample is admitted at atmospheric pressure, which is most simply accomplished by venting the sample line to the atmosphere at a point near the instrument. The standard gas is contained in a chamber with a mercury-sealed floating dome exposed to the atmosphere so that the monitored and standard gases are maintained not necessarily at constant pressures but at equal and slowly varying pressures which, in the presence of the self-calibrating feature, amounts to the same thing.

The sample passes by viscous flow through the primary leak into the sample manifold, which operates at a pressure of 1 mm. Hg. Over 99 per cent of the sample flows out of the manifold through the low pressure by-pass line, in which the pressure drop is principally due to the viscosity of the gas, through the inlet forepump, and thence out to a case vent. This system results in an extremely short response time, and very little "hangup" of sample. Furthermore, it can be shown that its use makes the pressure in the sample manifold almost completely independent of sample viscosity, which is an important feature.

The molecular leak is so proportioned that the gas flow through it is completely molecular in character. From this leak, gas flows into the ion source where it is ionized by an electron beam in a conventional manner. The molecular character of this leak, in combination with the by-passing technique just described, ensures that the partial pressure of each component in the ion source depends linearly on, and only on, the partial pressure of that same component in the original sample. Ion acceleration through the magnetic field, the separation of one beam from the remainder at the ion collector and the measurement of the resolved beam, are also basically conventional.

Normal operating pressure in the ion source is several times as high as the pressure immediately outside, which results in an important degree of suppression of "background" peaks compared to those due to the sample. This fact, combined with the use of an activated charcoal trap and the self-calibrating feature, has made it unnecessary to apply any correction for backgrounds in any problem thus far encountered.

The ion source and its associated mounting flange are shown in Fig. 2. Fig. 3 shows the mass spectrometer analyzer-magnet assembly. The analyzer is formed largely of stainless steel, and vacuum joints are sealed by Teflon gaskets in compression joints of conventional design. The magnet pole faces are equipped with "ears" in which the magnet gap is widened to accommodate the ion source at one end and the collector assembly at the other. Between these "ears" the magnetic field strength is about 40 per cent of that in the main gap, but this relation is constant. Consequently, there is ample magnetic field strength to collimate the electron beam in the ion source and to suppress secondary electrons at the ion collector. Also, ion beam trajector-

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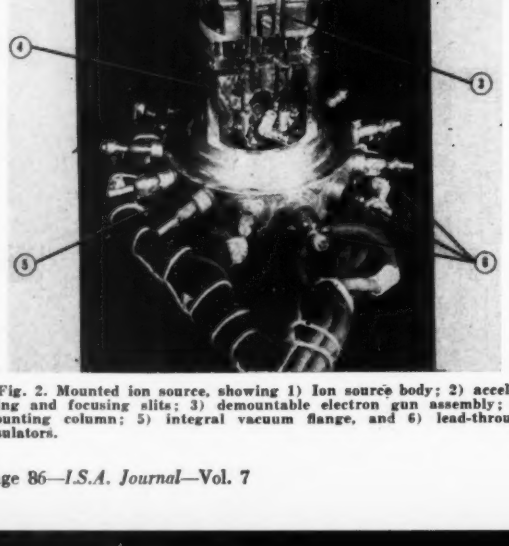


Fig. 2. Mounted ion source, showing 1) Ion source body; 2) accelerating and focusing slits; 3) demountable electron gun assembly; 4) mounting column; 5) integral vacuum flange, and 6) lead-through insulators.

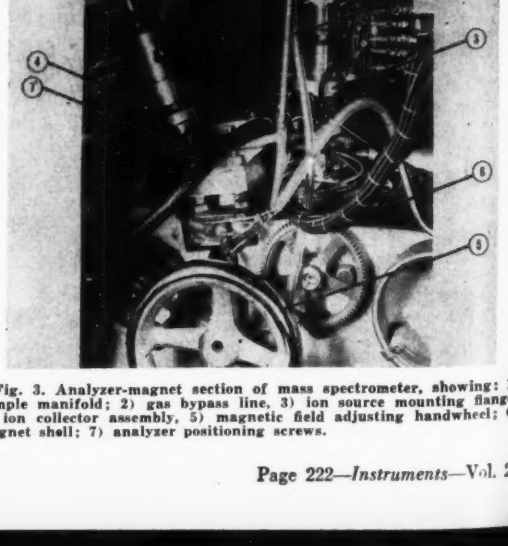


Fig. 3. Analyzer-magnet section of mass spectrometer, showing: 1) sample manifold; 2) gas bypass line, 3) ion source mounting flange; 4) ion collector assembly, 5) magnetic field adjusting handwheel; 6) magnet shell; 7) analyzer positioning screws.

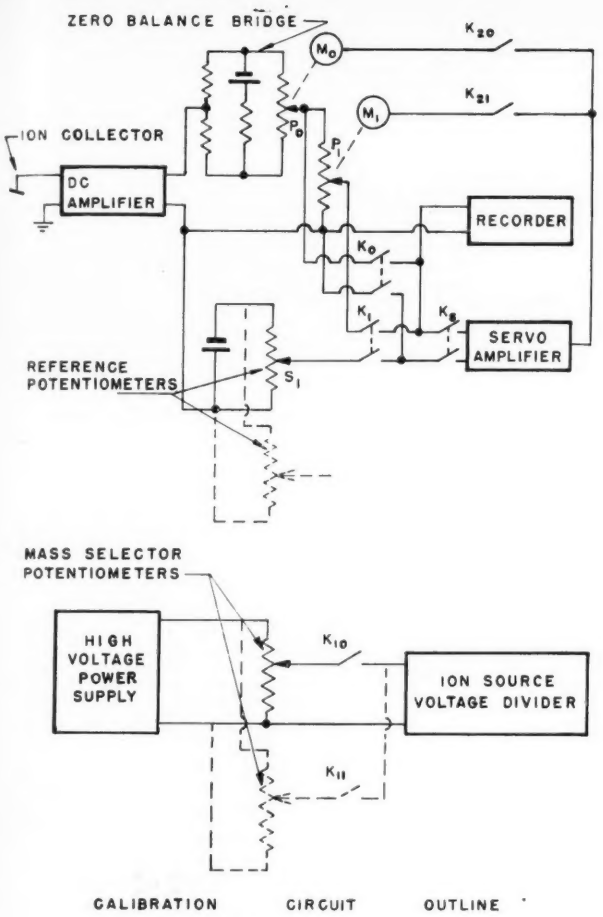
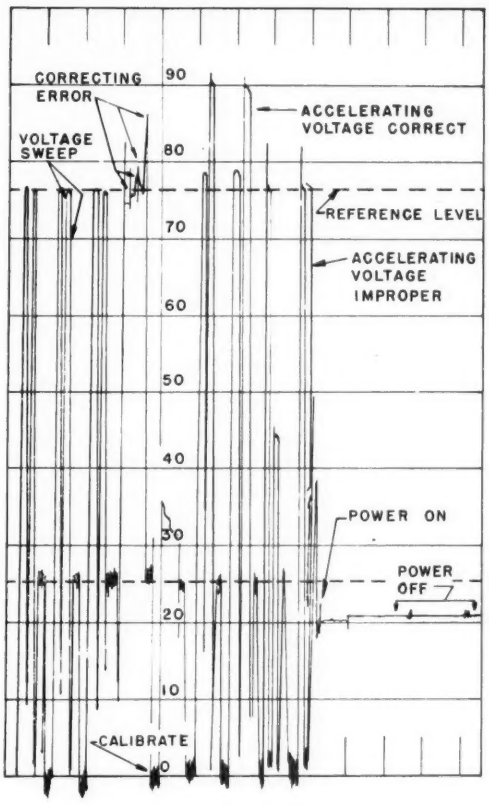


Fig. 4.



PORTION OF CHART—SHOWING AUTOMATIC RESTORATION TO SERVICE AND STANDARDIZATION

Fig. 5.

ies are nearly invariant to changes in the magnetic field strength.

The magnet is energized by Alnico V slugs, and the stability requirements are such that it has been necessary to thermostat the magnet to within 1° C. of constant temperature.

THE CALIBRATING CIRCUITS

Selection of one ion beam or another within any mass range of about 3 to 1 is accomplished by setting potentiometers V_1 through V_3 (Fig. 4). The part of the mass in which this octave and a half occurs is determined by manual setting of the magnet shunts, using the handwheel shown in Fig. 3, during the initial setting up of the instrument.

The ion current amplifier is conventional, the calibrating circuits being inserted in its output. For the sake of simplicity, Fig. 4 has been drawn so as to show only one complete channel of calibration; the operation of the remaining stages follows in an exactly similar way. The output signal from the d.c. amplifier is carried through the zero-balance wheatstone bridge to a set of channel potentiometers in parallel, here indicated simply by P_1. The voltage from the tap of P_1 is fed through K_1 to the recorder as shown; relays K_0, K_1, — K_8 are ganged with K_{10}, K_{11} — K_{18}; K_{20} K_{21} — K_{29} respectively so that the spectrum peak corresponding to the setting of K_{11}, the reference voltage corresponding to that of S_1, and the mass spectrometer output current corresponding to the setting of P_1 are held in correspondence. Such a group of components is called a "channel".

In the monitoring of a process stream, the zero level and the three peaks are scanned consecutively and repeatedly for 44 steps. On the 45th step, the sample valve switches the inlet system from the monitored gas to the standard, and the 45th and 46th steps are used for flushing the inlet system, which requires about 20 seconds. On the 47th step, relay K_0 is closed, and any potential developed across P_1 is fed into the input of the servo amplifier. From there the amplified signal is carried, through K_{20}, to motor M_0 which drives P_0 through the mechanical linkage shown, to null the potential on P_1. This calibrates the zero level of the system. On the 48th step, the potentials at the taps of P_1 and S_1 are fed through the two poles of K_1 to the servo amplifier; any difference between the two potentials is amplified and fed through K_{21} to motor M_1, which adjusts the tap of P_1 to null the difference. Now the voltage on the reference potentiometer S_1 is maintained constant with respect to full scale sensitivity of the recorder. Consequently the operation just described adjusts the sensitivity of the first signal channel (P_1) so that the recorder indication when standardizing on a stipulated mass peak of a sample of known composition — the standard — shows accurately a preassigned reading (the manually preset reading of reference potentiometer P_1). The remaining channels are standardized in an exactly analogous way on steps 49 and 50 respectively, while steps 51 and 52 are used for switching the inlet system back to the process stream.

The standardizing operation just described is performed with an overall accuracy of about ± 10 microvolt, or ± 0.1 per cent of full scale for a 10-millivolt recorder. Recorder errors, paper shrinkage, and whatnot can build the total errors, in unfavorable cases, to 50 microvolts, or 0.5 per cent of full scale on a 10-millivolt instrument. Standardization compensates rigorously for changes in the zero level and the overall sensitivity of the instrument, due to whatever cause, and compensates, to a degree which varies from one problem to another, for variations in the relative peak heights in the various mass spectra involved. The total time that the instrument is "off stream" for standardizing is a little under 2 minutes, and an entire cycle of 52 steps requires about 10.5 minutes.

It will be seen that the instrument records the mass peaks not only in monitoring, but in standardizing as well. Thus the instrument not only corrects its own errors, but demonstrates, by recording the standardized

levels, that it has done so. This periodic exhibition of the instrument's sensitivity on a standard sample is fully as valuable in avoidance of instrument errors as the standardization itself; indeed, it is anticipated that there will be many applications in which periodic exhibition of the various channel sensitivities, with or without means for manual error correction, will supplant the automatic standardization provided here.

During standardization, the various voltages are held constant. During monitoring, however, the ion accelerating voltages are not strictly constant, but are varied symmetrically from a level slightly above to one slightly below the nominal voltage. The result is that the instrument does not remain

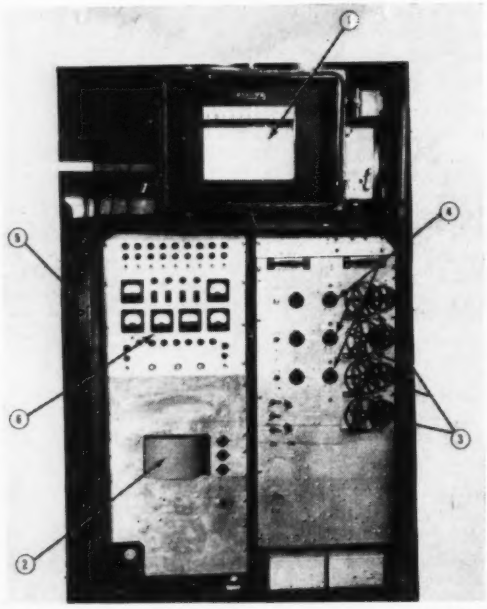


Fig. 6. Front view of mass spectrometer with pressurizing bulkhead removed, showing: 1) strip-chart recorder; 2) heat exchanger; 3) calibrating servo gear trains, 4) reference voltage potentiometers; 5) auxiliary control panel; 6) control panel, visible through window in bulkhead, (not shown).

on the top (or, in case of an accidental voltage shift, on the side) of a mass peak, but shows the top and a limited part of each side of each peak. Consequently even an inexperienced operator can tell whether the instrument is properly centered on the peaks (or, in the case of the zero channel, on a valley free of peaks), and can also tell at once if any instrumental malperformance should cause the peak shapes to deteriorate. These two features—the exhibition of the channel sensitivities on a standard sample and the exhibition of the peak shapes during monitoring—make the instrument automatically warn the operator of any malfunction which might cause errors in the record.

APPLICATION

A detailed analysis shows that this instrument, like most such instruments, has its maximum resolving power and its maximum absolute accuracy when it is used as a detector of differences between an unknown sample and one of known or "standard" composition. It is possible to take advantage of this fact and simultaneously to achieve a particularly simple record presentation by providing a standard gas whose composition is the optimum for the particular process stream involved and to set the reference potentiometers so that the instrument shows all of the various mass spectrum peaks to be of equal height when standardizing on this gas. Departures of the process stream composition from optimum are instantly revealed by failure of the peak tops to line up when the instrument is monitoring the process stream, and quantitative interpretation of the difference is usually fairly simple. A second method, a little more complicated to set up and too complicated to describe in detail here, avoids the necessity of synthesizing a mixture of exactly optimum composition.

Let us now consider an actual problem to which the instrument has been applied. The first such problem was the detection of ethane in the effluent stream from a refinery de-ethanizer. The stream consists principally of C_3 to C_5 hydrocarbons, propane being the major constituent. All of the constituents show peaks at masses 29 and 30, but ethane is the only one whose contribution to the 30 peak is not due to heavy isotopes from mass 29. Consequently the instrument is set so that, when standardizing on an ethane-free standard, the mass 29 and mass 30 peaks are equal at about 40 per cent of full scale on the recorder. (See Fig. 5), The presence of ethane in the monitored stream is made evident by inequality in the heights of the mass 30 and mass 29 peaks, the mass 30 peak being higher than the mass 29 by about 0.3 scale divisions per 0.1 mol percent of ethane in the refinery stream. Under favorable circumstances, this sensitivity can be about doubled.

If no further information is required, pure propane can be used as a standard gas and the third record channel gain set to an arbitrary level (say zero) and left there. If information on C_4 pariffins is desired, still using pure propane for standardizing, channel 3 is set to mass 43, setting the channel to standardize at say 60 per cent of full scale. Butane is revealed by the 43 peak's being higher in monitoring than in standardizing. In this case, the difference is about 0.3 seale divisions difference per 0.1 mol per cent Butane in the monitored stream. The problems to which this instrument can be applied are so many and so varied that it is almost impossible to set down any all-inclusive rules for its use, and it is certainly not feasible to attempt to do so here. The process engineer, in considering the application of the instrument to his problem, is constrained to masses below about mass 100 covering a mass range of perhaps 3 to 1, and to reasonably volatile materials. The decisions as to the number of peaks to use and which ones to use, the manner of presentation of the record, the type of standard gas to employ and the levels to which the instrument should standardize when running it, will be dictated by the details of the process and the aims of the process engineer.

GENERAL FEATURES

The instrument is equipped with a vapor-tight case designed to be pressurized at a few tenths of a pound per square inch. A general view of the instrument with the front bulkhead removed is shown in Fig. 6. Safety interlocks shut the instrument down in case the internal pressure should fall below a safe value. Most of the internal heat developed is removed by the exchanger shown. A limited number of controls placed on the auxiliary panel shown, and available from outside, can be manipulated without shutting down the instrument; these are used for regeneration of the charcoal trap, trouble shooting, initial adjustment, or initial calibration.

A complete set of interlocks is provided to protect the instrument from most ordinary hazards. The mass spectrometer analyzer and filament are protected against vacuum failure, and the diffusion pumps are protected against failure of either the backing pumps or the cooling water. A set of interlocks is provided to ensure that the various voltages will be applied in the correct order, and an associated set of time delay relays ensures that in case of a power failure of limited duration (up to a minute or two) the instrument will automatically restore itself to service, turning on each component automatically in the proper sequence and after the proper time delays, until the instrument is once more in full operation.

SERVICE REQUIREMENTS

The minimum service requirements of the instrument are that the recorder chart paper and ink be replenished every forty-eight hours of operation; it is not necessary to shut down the instrument for this purpose since the recorder case is separately pressurized. About 2.8 kilowatts of power and about 20 pints per minute of cooling water are required. No cold trap are employed. The uninterrupted service life of the charcoal trap is not definitely established but it is at least six weeks and may be much more, and the trap can be regenerated while in place, without removing the case bulkheads. The

investigation of the applicability of the instrument to various problems has thus far prevented any really extended continuous operation, the longest period during which the instrument has run entirely without adjustment being about six weeks.

ACKNOWLEDGEMENT

The initial tests of this instrument have been greatly facilitated by the cooperation of the Research and Development Division, Socony-Vacuum Laboratories, Paulsboro, New Jersey and by Esso Laboratories, Esso Standard Oil Company, Louisiana Division, Baton Rouge, Louisiana.

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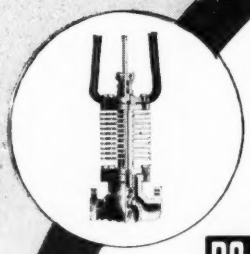

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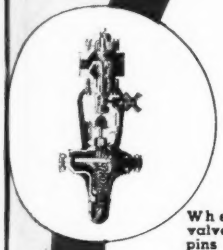

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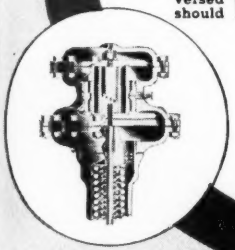

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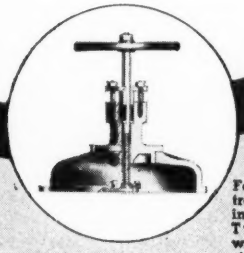

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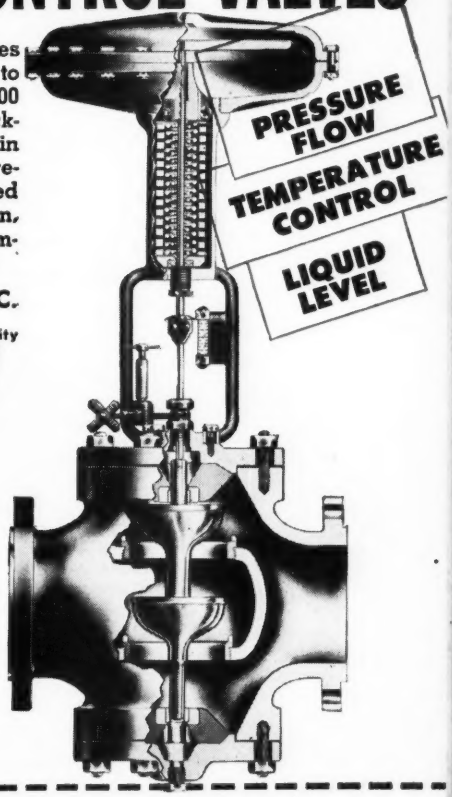

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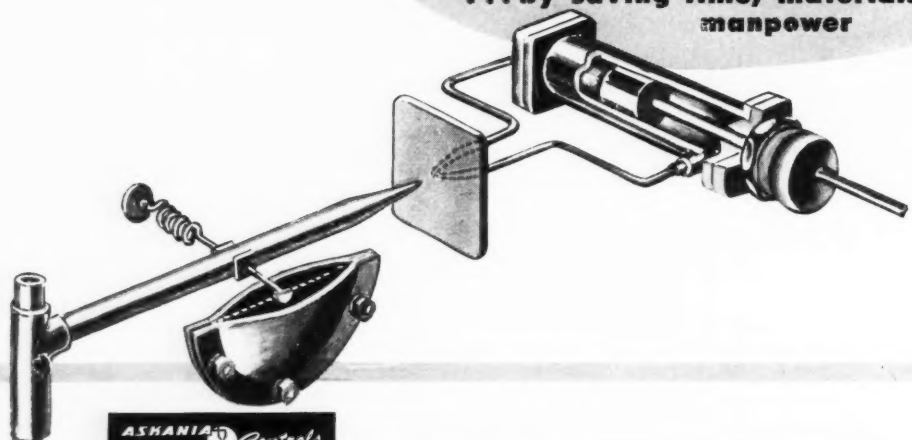

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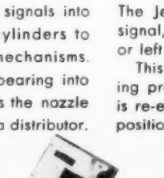

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ROTAMETERS

By W. J. BECKETT, Bushnell Controls & Equipment Co.

Introduction

FLOW measurement is indispensible to our modern industry. Flow instruments are used to control plant processes, to fix ratios of materials during continuous operations, to determine what actually happens, and to determine the economics of the process involved.

This discussion will be necessarily limited to one type of flow meter, namely, the rotameter, which is the simplest, most accurate device for the measurement of fluid flow, that has ever yet been devised.

Definition

A rotameter comprises a tapered glass tube fastened in a vertical position in the line of a pipe, in which the fluid is flowing, with a specially designed float that fits snugly at the bottom of the tube. As soon as flow commences, the float rises with the fluid toward the top of the tube. As it rises the annular passage between the float and the tube increases until all the fluid coming thru the pipe is allowed to pass. When this occurs and the float comes to rest, its weight exactly balances the velocity pressure of the fluid plus the float's own bouyancy (Fig. 1). Hence, it provides a visible measurement in which the actual fluid itself and its flow through the pipeline can be seen and the variation in flow observed in relation to a calibrated scale.

The rotameter was invented in 1868 by the Frenchman, Chameroy. An area meter based on a tapered tube. Next was Joslin's British patent in 1879 describing a glass tapered tube with a disk type float for gas measurement.

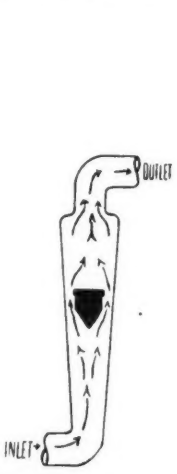

Fig. 1 (Above) Principle

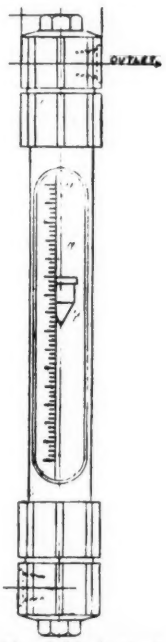

Fig. 2 (Right) Instrument

Then came Kupper's German patent in 1908 that added the idea of slotting the float head to impart the characteristic spinning float action which inspired the name "Rotameter." American leadership in this field became established in the early thirties.

Uses and Applications

The rotameter is primarily a local indicating instrument with a uniform scale calibrated for any unit of measure (Fig. 2). An electric transmitter (Fig. 3) has been added to operate remote instruments. This method is known as the "Null balance inductance bridge circuit."

Combinations available are: Indicating; Recording; Recording Intergrating; Indicating Recording; Indicating Recording Intergrating; Recording Controlling, Air output; Recording Controlling, Electric output; Proportioning, Electric Control—Alarm Signals.

Uses: Rotameters are commonly used for metering gases, vapors and liquids —opaque or transparent, two exceptions being hot caustic and hydrofluoric acid either of which attacks the glass tube.

Rotameter capacities, Sizes, Pressures—Approximate Limitations:

Water	*Air*
Min.—2-10 CC/min.	Min.—200 CC/min.
Max.—800 GPM	Max.—1000 CFM
Pipe Sizes	*Pressures*
Min.—⅛" N.P.T.	Min.—1" W.G.
Max.—6" N.P.T.	Max.—3000 psig.

Selection

Rotameters are fundamentally designed for accurate measurement of small flows and it is not practical or economical to extend too far into the range of head type or orifice meters.

The rotameter has many basic advantages for flow measurement, among them the following:

Accuracy: The rotameter has a high reproductible accuracy; it will consistently repeat its indication of a given flow. It also has high reading accuracy because of its basically long scale which in the standard length is 10 inches and in the extra length is 25 inches. Ac-

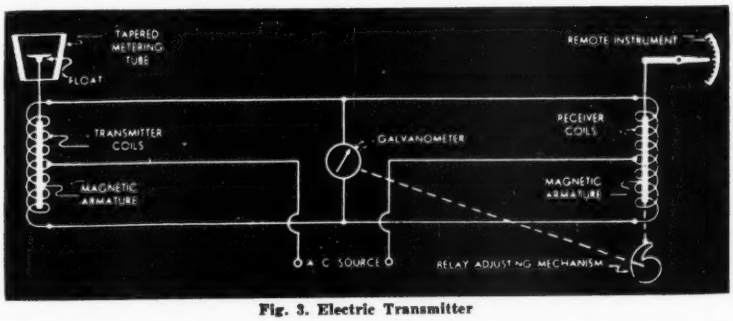

Fig. 3. Electric Transmitter

* Presented at a meeting of the Southern California Meter Association.

March Meeting: Thursday the 15th, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30, Meeting at 8:00 p.m.

Feature: "Process Factors which Affect Automatic Control," by J. B. McMahon, President, Instrument Society of America.

curacy as high as 99.0 percent can be obtained in the standard length meter and as high as 99.5 percent in the extra length extreme accuracy design. There is no friction, no lag, no hysteresis to affect this accuracy, and the glass tube.

Resistance to Corrosion: The pyrex borosylicate glass tube resists the action of practically every fluid except hydrofluoric acid and hot caustic. Meter fittings and the float also can be made to resist the action of corrosive chemicals by using such materials as stainless steel, duriron, hastelloy, ceramics, rubber, monel, plastics, Everdur or other special bronzes and other materials.

Uniform Scale: Calibrations on a rotameter scale are evenly spaced and wide apart. The lower part of the scale can be read as easily as the upper part.

Constant Low Pressure Drop: Pressure loss through the rotameter is low and practically constant at all flows. The annular opening between the float and the bore of the tapered glass tube enlarges as the float rises on increase of flow.

Easily Cleaned: The necessity of cleaning is readily seen because of the transparent glass tube. Cleaning can quickly and easily be accomplished through top and bottom clean-out openings without the necessity of removing the rotameter from the pipe line.

Low Maintenance Cost: The simplicity of the rotameter's only one moving part—the float—implies the minimum of wear. In the free float construction there is no mechanical friction; in the case of the guided float construction, the friction is extremely small.

Wide Range: Ranges from maximum to minimum of 20 to 1 are common in rotameter construction and even wider ranges may be obtained. The rotameter has the widest range of any flow rate measuring device.

Immediate Response: If the rotameter is absolutely free, it responds instantly to the slightest change in flow. This is of great value to the operator for thus he knows instantly when the flow rate changes from the specified amount.

Low Installation Cost: The rotameter lends itself easily to the regular flow piping and its installation is negligible compared to the expensive layout of orifice meter runs.

The disadvantages of rotameter are several. The glass tube—the "heart and soul" of the rotameter—is breakable, due to an external or excessive shock, pipe strains, and even quick temperature changes. In such cases, the rotameter becomes a fire hazard and can be a source of injury to operators. Rotameters are constructed with two stuffing boxes which in severe services presents considerable maintenance and loss of valuable fluids. In case of the remote transmission systems which are expensive, the basic difficulty of all flow meters using induction bridge transmitters has in the past been the seemingly incurable effect of temperature changes on the resistance (and therefore the balance points) of the impedance coils. However, one rotameter manufacturer does claim a new development wherein the transmitter is not appreciably affected by temperature changes. Also, there will be many instances where gases and liquids will continually form deposits on the inside of the rotameter tube and the float, therefore affecting visibility and accuracy and requiring frequent cleaning.

Construction

The success of the rotameter as an accurate flow measuring device is based on the precision bore glass tapered tube. The dimensional tolerances to which these tubes are held are such that each tube of given size is interchangeable with any other of this size. The complete fidelity of this interchangeability requires adherence to tolerances of 0.0002 in. for the smaller tubes—a thoroughly remarkable production performance. The tapered glass tube is formed in a metal mandrel so that the accuracy and mirror-like internal smoothness of the glass tube naturally depends on the dimensional accuracy and finish of the stainless steel mandrel. Rotameter scales are in some instances etched on the rotameter tube itself. At least one manufacturer offers a removable calibrated scale lying in close proximity to the metering tube which permits changing from one service to another merely by changing to the appropriate scale. In the case of rotameter floats, there are two classifications—the *free float* and the *guided float*.

The free float is the absolute in simplicity. There is only one moving part which is itself the primary meter and the ultimate indicator. There is no friction whatsoever, hence no hysteresis, and if the tapered tube is kept clean there is no reason readings cannot be reproduced to within the capacity of the observer's eyesight. The above depends on one prime factor and that is that the float be in the exact center of the tapered tube for all readings and that the float does not wobble or oscillate. The top-shaped free float, quite satisfactorily meets these conditions, but when constancy must be met, the free center guided type takes care of such jobs.

The guided float when properly made is almost frictionless, being bushed for only two points of contact on a stainless steel guide wire. The bushings are characteristically rounded and are of stainless steel, glass or sapphire jewels. Greater accuracy is secured by means of the guide rod since the float is always properly aligned with respect to the metering tube. The guide rod makes sure that accuracy is maintained since it is impossible for the float to change the shape of the annular area by oscillating. Furthermore, greater flexibility is obtained, and while the free float must be designed along specific lines to insure stability, the guided float retains stability although specifically shaped.

Dimensional and weight floats to overcome the problems encountered in certain specific services are as follows:

a. Density compensation guided floats can be used where the inaccuracy due to normal changes in fluid density must be overcome.

b. Uni-vis guided floats can be used where inaccuracies due to normal changes in fluid viscosity must be overcome.

c. Small diameter ratio guided floats can be used to decrease the flow range to as low as 2 to 1 or less.

d. Light weight ratio guided floats can be used to reduce the pressure drop through the rotameter to the absolute minimum.

Uni-vis floats are used to avoid viscosity effects. Studies of viscosity effects reveal that special shaping of the float will maintain the flow efficiency—coefficient at practically constant flow and will nullify almost entirely the effect of viscosity changes.

With the conventional plumb-bob rotameter, a slow increase in fluid viscosity tends to lift the float upward because of the large surface area exposed to surface drag. Moreover, the stream pattern varies greatly with changes in temperature. Almost complete immunity from these effects can be secured by a float made up of a sharp edged disk with a body portion small in diameter but of sufficient length and with suitable density to secure the desired float weight. Therefore with such a float, almost identical turbulence is produced over a wide range of fluid velocities.

Guided plastain floats achieve very satisfactory density compensation. If the unit of measurement is in terms of weight, a means for self-compensation, for changes in density of fluid is presented by the basic rotameter principle. An inspection of the governing formula will reveal the fact that by making the float density equal to twice the density of the metered fluid, a mean compensation is secured; the rotameter is then practically independent of fluid density when the scale is in weight units. Particularly in gasoline measurement, this result may be accomplished by making the sharp edged disk portion of stainless steel and the cylindrical body of plastic. This combination of plastic and stainless steel gives the float the name "Plastain." For density compensation, a plastain float should be specified.

Good stuffing box design is extremely important in a rotameter to obtain a leak proof joint between the tapered glass tube and the metal end fittings which join it to the pipe line. The stuffing box should be provided with at least two packing rings of sufficient depth and wall thickness to provide for a secure seal on the glass tube. The packing adjusting ring should be of ample strength and easily adjustable with a spanner or strap wrench.

Dashpot rotameters for pulsating flows are designed especially for accurate rate of flow measurement of pulsating flows. Since the calibration curve of the rotameter is a linear function which therefore results in evenly

spaced graduations on the calibration scale, the *mean* rate of flow is accurately determined by obtaining the linear mean distance between the extremes of flow. To eliminate the difficulty in attempting to determine the mean distance between extremes of pulsation by observation, there is placed either above or below the meter body an *extension* containing a precision-bore gage glass in which a closely fitting piston attached to the metering float functions to indicate the average rate of flow. Any desired degree of dashpot effect is possible through design of the piston. Where it may be necessary to vary the degree of dashpot effect after the rotameter is in service a by-pass containing a needle valve across the dashpot extension can be employed. The desired dashpot effect can then be obtained by adjusting the valve.

Rotameters for opaque fluids are recommended where difficulty in reading the position of the metering float may be encountered because of fluid opacity. To overcome this difficulty, an extension containing a precision-bore gage glass is attached to the meter body either above or below as desired. A closely fitting piston attached to the metering float and extending into the gage glass indicates the rate of flow through the rotameter. The diameter of the piston is only a few thousandths of an inch smaller than the inside diameter of the gage glass, thus permitting only a thin film of fluid, not enough to obscure the piston, between the piston and gage glass.

Rotameters for vapors containing condensibles are available to eliminate the inaccuracies arising from the tendency for condensate to *collect on the float*. This type is similar to the dashpot and opaque extension rotameters, the difference being in the type float used. The metering float is hollow and is connected to the piston by a hollow tube. Condensate collecting on the metering float drains into the extension which for this type must, of course, be attached below the meter body. By appropriately connecting a drain or stream trap, the lower extension can be maintained *empty* or *full* of the liquid depending on the degree of dashpot effect desired.

Summary

In the rotameter we have a most simple and inexpensive device, yet the most accurate and the most adaptable flow instrument fundamentally designed for use in an all-important field of small and medium flow processes. Its popularity and usefulness is well deserved and is highly appreciated, because, with a rotameter one can SEE "what goes on" as it measures.

Industrial Applications *of* Manometers

By CHARLES MERIAM, Mgr., Western Division, The Meriam Instrument Co.

SOME have said that the name manometer sprang from the use of a leathern bag and vertical glass tube filled with mercury and squeezed by a man to indicate the strength of his fingers—man meter—hence manometer. While such a device no doubt was amusing, it was the Greeks who had two words for it in the origination of the term manometer. The Greek "manos" meaning rare and "metron" meaning to measure were combined to form manometer which today means a "rare" or light-pressure and low-differential indicator. Through usage the term has come to most often mean a mercury or fluid-column pressure indicator.

Manometers have been used for hundreds of years, possibly thousands. One of the best known of the early manometers was the sixteenth century Torricelli Tube of mercury manometer which indicated the atmospheric pressure. The average individual sees a manometer each time he has his blood pressure taken. Physicians call it the sphygmomanometer.

Though manometers have been used for such a great number of years, the term is still not widely known. Many engineers think of a manometer as a classroom oddity of their school days. They miss the fact of the intrinsic accuracy of the fluid-column manometer as it balances pressure against gravity.

It was back shortly after 1900 that Mr. Meriam first designed the commercial U-tube manometer with protecting metal case and cement packed tubes to provide for pipe connections. He used the manometer to show the pressure drop around a 0.75-in. orifice in a gas line supplying a large stationary gas engine. Watching the manometer, he was able to see improvements in gas economy as he made close adjustments to the engine mixing valve and ignition. Laying the manometer on an incline he increased its sensitivity and called the unit the "Gas Economy Indicator." Some are still in use today as obviously a manometer can never wear out. The manometer has been applied in thousands of ways. Interestingly though, one large use of manometers is still in indicating the flow of air and fuel to engines. In operating engines and particularly in testing them after assembly the manometer has not been excelled.

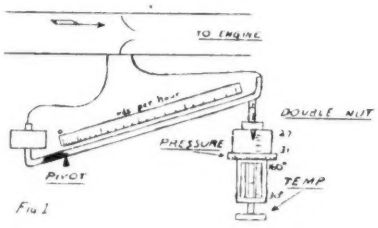

Fig 1

The test engineer desires to know the flow of air to the engine in lbs. per hr. so that he may know his air-fuel ratio.

An orifice or flow nozzle is inserted in the air line and an Inclinometer (incline-tube manometer) is used to measure the pressure drop around it. The incline tube is hinged at the bottom as shown schematically in Fig. I and a double adjustment is used at the upper end. As the temperature of the flowing air increases the volume is greater though the weight of air is the same. Raising the incline keeps the fluid meniscus at the same pounds-of-air reading. As the pressure on the flowing air increases the volume is less though the weight remains the same. Lowering the incline keeps the fluid meniscus at the same pounds-of-air reading on the square root scale. The operator adjusts the pressure and temperature compensators as often as necessary, and the Inclinometer always indicates the pounds air per hour.

The Inclinometer having been developed before the war proved of tremendous worth in the testing of the thousands of aircraft engines built for war service. Every one has been test operated with the Inclinometer metering the air consumption.

An ingenious application for a similar adjustable incline manometer was found at a chemical company engaged in the artificial rubber program. In determining the gravity of gases the high and low pressure ends of the incline were connected to 30 foot stand pipes. There were two approximately 0.5-in. copper tubes run up inside a 1-in. steel pipe support. By suitable valving a base gas (in this case hydrogen) and the gas in question were flushed through the vertical copper tubes to completely purge them. A twist of the valves brought the weight of the column of hydrogen against the upper end of the incline and the weight of the lower end. The gravity was immediately indicated on the scale of the incline manometer. Raising or lowering the incline permitted use of different base gases. Gravities determined on the Inclinometer were correct to one place in the third figure with values determined molecularly by the laboratory. In addition they were obtained in a few seconds at any time.

A valve manufacturer was permitted a certain leak on relief valves. His inspection department put them under pressure and submerged them in water. If the bubble rate was high they were rejected; if low they were passed. There was a maximum of human element and the valves had to be carefully dried after test. The test fixture was modified to include a chamber of definite size into which the leakage was caught. A manometer was connected to the chamber. If the valve leaked enough to fill the chamber to too great a pressure as indicated by the manometer in a given time, the valve was rejected. To

* Presented at a meeting of the Southern California Meter Association.

Operation and Care of Circular-scale Instruments

By

JAMES SPENCER

For 20 years in charge of Instrument and Relay Department, Meter Div., Westinghouse Electric Corp.

CONTENTS

EDITOR'S FOREWORD

AUTHOR'S PREFACE

CHAPTER I—ESSENTIAL TOOLS

CHAPTER II—D-C. INSTRUMENTS

Dismounting and Reassembling. KX-124 Instruments, DB-12 Instruments, Test and Inspection, Principles of Operation, Maintenance, Connections.

TROUBLE CHART FOR D-C. INSTRUMENTS

CHAPTER III—A-C. AMMETERS AND VOLTMETERS

Principles of Operation, Construction, Dismantling KA-24 Instrument, Reassembling, Dismantling DB-12 Instrument, Test and Inspection, Internal and External Connections, Maintenance.

CHAPTER IV—ELECTRODYNAMIC TYPE INSTRUMENTS

WATTMETERS, Construction, The KF-24 Wattmeter, The AB-12 Wattmeters, Connections, Principle of Operating, Inspection and Calibration, Single-phase Wattmeter, Poly-phase Wattmeter, Maintenance.

FREQUENCY METERS, Construction, The KF-24 Instrument, The AB-12 Instrument, Principles of Operation, Test and Inspection, Maintenance.

CHAPTER V—POWER FACTOR METERS AND SYNCHROSCOPES

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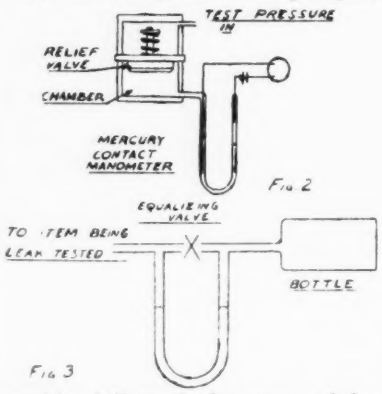
save the operator, a contact rod was set above the mercury, and a light was connected as shown in Fig. 2. If the light lit within the time limit the valve was immediately rejected.

A somewhat similar leakage indicator but one having more widespread application is the manometer, equalizing valve and bottle, Fig. 3. The bottle, a chamber of approximately one quart volume, is leakproof. The unit is connected to the pipe section, tank or piping installation to be tested. The valve is opened and both chamber and item to be tested are put under the same pressure. The valve is closed. The fluid in the manometer moves quickly if there is only a tiny leak for it is sensitive to a very small drop in pressure. This device has wide application wherever leakage tests are made.

For calibrating aneroid diaphragms,

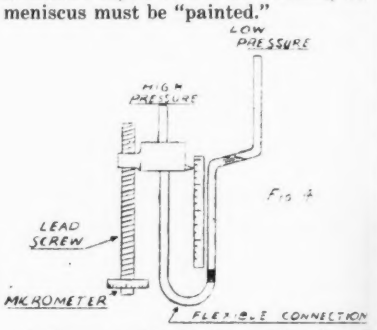


sensitive bellows, hook gages, and for reading low velocity heads directly an indicator reading in thousandths of inches of water is desired. The micromanometer was developed to fill the need, for again a master standard device was required.

The micromanometer is of the well type. The pressure to be measured forces the fluid up the vertical tube away from its zero setting which is directly behind the hairline on the incline (Fig. 4). Operation of the accurate leadscrew lowers the well and meniscus until the meniscus is again directly behind the hairline. The inches, tenths, hundredths, and thousandths are then read on the vertical scale and micrometer wheel. The sensitivity of the micromanometer depends much upon the fluidity of the manometer fluid. A special water was developed having a very precise amount of wetting agent and non-staining dye. By using the special gravity 1.000 concentrate in distilled water as the indicating fluid each thousandth inch of water pressure moves the meniscus nearly a full thirty second of an inch on the incline. The movement is easily seen. The micromanometer is a massive instrument, for wherever minute differences are to be indicated no substitute is found for heavy rigidity.

In the calibration of low differential flow meters and in some cases the calibration of the higher range flow meters a manometer reading closer than inches and tenths is desired. A vernier manometer reading inches and hundredths is one good answer. The height of the usual manometer and the need for a ust-tight closure around its tube makes a sliding vernier and hairline difficult to operate. A continuous group of verniers on a separate scale throughout the length of the manometer is the design answer. Wherever the meniscus comes to rest, there is a vernier hairline less than half an inch away. A few turns of the simple external adjustment connected to the vernier scale moves all the verniers until the nearest one is aligned with the meniscus.

Naturally no vernier manometer or any other highly accurate and sensitive manometer can be correctly used unless the pressures being measured are fixed. The fluid meniscus must be at a standstill or, as it is often termed, the meniscus must be "painted."



A fine example of the application of a sensitive manometer to a baffling industrial problem is the locating of leaks in gas protected telephone cables. Moisture in lead-sheathed telephone cables destroys its efficiency and greatly increases maintenance costs. To keep out moisture the cables are filled with inert gas (nitrogen, helium, etc.) under a pressure of about 20 pounds. The gas filters around the wire bundle and in case the lead sheath is punctured it flows out to prevent moisture coming in.

Some cables are overhead and many are buried ten to twenty feet. Insects in the air, rodents, growing roots, or vibrations in the ground open tiny holes in the cable. Pressure stations are maintained about every three or four thousand feet of cable. The problem of locating a pin hole leak somewhere in the three thousand foot length would seem difficult. Where consumption of gas indicates a leak, a pressure gradient is established with the manometer. Reading in hundredths of pounds, minute pressure differences between standard pressure taps on the cable are indicated. The pressure drop curve from one pressure station crosses the pressure drop curve from the other and the intersection locates the leak. Using the manometer carefully, the fieldmen generally locate the leak within a few feet. Only one excavation is required.

Only several manometer applications have been mentioned. Actually there are thousands. The fundamental accuracy of the manometer principle and the direct way in which the principle can be applied makes it easiest for the plant men to use a laboratory standard "at the job."

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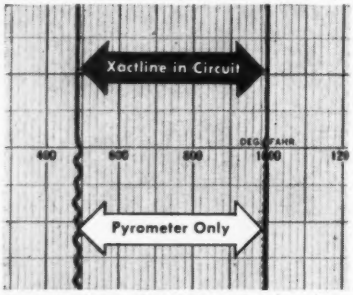

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Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

T-106 LABORATORY SUPPLY CATALOG. 980-page Catalog 450 illustrates and describes supplier's line of scientific apparatus and laboratory chemicals.—Burrell Corp., Pittsburgh 19, Penna.

T-107—TAPE RECORDER. 2-page Bulletin 2J6934 illustrates and describes maker's professional tape recorder type RT-11A; lists features and specifications.—Broadcast Equipment Section, RCA, Engineering Products Dep't, Camden, N. J.

T-108 POLARISCOPE. 4-page catalog illustrates and describes maker's high-intensity polariscope; includes features and applications.—West Shore Laboratories, Box 117, Marblehead, Massachusetts.

T-109 COUNTERS. 4-page bulletin describes and illustrates maker's predetermining counters; includes applications and operation.—Streeter-Amet Co., 4101 W. Ravenswood Ave., Chicago 13, Ill.

T-110 MANOMETER. 12-page Catalog Section 42 illustrates and describes maker's kinetic manometer for flow metering; gives specifications and typical installations.—Fischer & Porter Co., Hatboro, Penna.

T-111 ELECTRONIC CONTROL SYSTEM. 8-page Bulletin 1100 illustrates and describes maker's "Telemaster" electronic master control system; discusses features, operation and advantages.—Republic Flow Meter Co., 2240 Diversey Parkway, Chicago 47, Ill.

T-112 POWER SUPPLY. 2-page Bulletin T-128 illustrates and describes maker's "Unibridge" power supply and bridge control unit; includes specifications.—Industrial Electronics, Inc., 8060 Wheeler St., Detroit 10, Mich.

T-113 LABORATORY SAFETY. 40-page manual on recently developed data, techniques and equipment for laboratory safety.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.

T-114 RELAYS. 8-page Catalog 17 and price list illustrates and describes mercury plunger relays; includes specifications and diagrams.—Dept. MP 44, H. B. Instrument Co., 2633 Trenton Ave., Philadelphia 25, Penna.

T-115 A-C. OUTLET. 1-page bulletin describes and illustrates maker's miniature a-c. outlet; UL approved.—Alden Products Co., 117 N. Main St., Brockton 64, Mass.

T-116 GAGE BLOCK JACK. 4-page bulletin illustrates and describes maker's gage block jack to aid in cutting inspection time.—Mechanical Div., General Mills, Inc., 1602 Central Ave., N.E., Minneapolis 13, Minn.

T-117 MICROMETER. 4-page Bulletin A-101 illustrates and describes seven custom-built electronic instruments including micrometer, power supplies and calibration of line voltage.—Industrial Electronics, Inc., 8060 Wheeler St., Detroit 10, Mich.

T-118 SAFETY SWITCH. 40-page Bulletin 7500 illustrates and describes maker's "Autocon" hi-level safety switch that works on compressed air.—Automatic Control Co., St. Paul 4, Minn.

T-119 PRODUCTION COUNTERS. 8-page Bulletin EC-42 illustrates and describes maker's dust-proof, panel mounting and standard electric counters; includes dimensional diagrams and prices.—Production Instrument Co., 702 W. Jackson Blvd., Chicago 6, Ill.

T-120 TUBE SUBSTITUTION. 40-page reference manual for substitute types of radio and television tubes; change-over diagrams included.—Radio Tube Div., Sylvania Electric Products Inc., Emporium, Penna.

T-121 AMPLIFIERS. 4-page Form 2J6358 illustrates and describes maker's "BN-2A" remote amplifiers; includes features and specifications.—Broadcast Equipment Section, RCA, Engineering Products Dep't, Camden, N. J.

T-122 ANGLE COMPUTER. 4-page Bulletin 4 illustrates and describes maker's compound angle plate which can hold work in any position of 0 to 90 deg. in two planes.—Angle Computer Co., 1709 Standard Ave., Glendale 1, Calif.

T-123 LOW RANGE LIMITS BRIDGE. 4-page Bulletin 8A illustrates and describes maker's "Speed Sort" low-range limits bridge.—Associated Research Inc., 3758 Belmont Ave., Chicago 18, Ill.

T-124 HAND TACHOGRAPH. 2-page bulletin illustrates and describes maker's "Model G-12" portable hand tachograph; includes specifications and dimensions.—O. Zernickow, 15 Park Row, New York 7, N. Y.

T-125 WATER STILLS. 8-page house organ, July 1950 issue of "Preiser News," features article on "Principle and Operation of Water Stills"; includes section on new laboratory equipment.—B. Preiser Co., Inc., 416 W. Washington St., Charleston 2, W. Va.

T-126 CONTROL VALVES. 10-page brochure features article entitled "Dynamic Force Reactions in Double Ported Control Valves"; includes charts and engineering diagrams.—Fisher Governor Co., Marshalltown, Iowa.

T-127 COLORIMETER. 4-page bulletin illustrates and describes English-made "Hilger" apparatus designed to simplify colorimetry (absorptiometry).—The Jarrell Ash Co., 165 Newbury St., Boston, Mass.

T-128 TRANSMITTER-CONTROLLER. 6-page Bulletin 11-1 illustrates and describes maker's differential-pressure transmitter and flow transmitter-controller; includes engineering diagrams.—Moore Products Co., Philadelphia 24, Penna.

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T-131 SCINTILLATION COUNTING. 8-page catalog illustrates and describes four of maker's scintillation counting equipments; includes application, features and specifications.—R-C Scientific Instrument Co., 335 Culver Blvd., Playa Del Rey, Calif.

T-132 ALUMINUM. 96-page handbook illustrates and describes the "How, Why, Where and What" of aluminum; includes historical background and illustrations of all operations and applications.—Reynolds Metals Co., Louisville, Ky.

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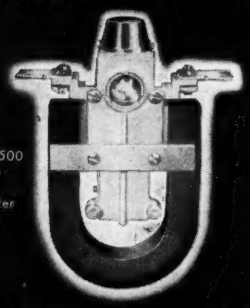

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T-134 STEAM-JET SYPHONS. 4-page house organ, Vol. 2, No. 2 issue of "Engineering News," features article on three-fold function of steam-jet syphons.—Schutte & Koerting Co., 1185 Thompson St., Philadelphia 22, Penna.

T-135 KLYSTRON SUPPLY. 4-page house organ, Vol. 2, No. 4 issue of the "hp Journal," features articles on low-power klystron supply; article on repair of maker's line of instruments.—Hewlett Packard Co., 395 Page Mill Road, Palo Alto, Calif.

T-136 ELECTRIC FURNACE. 8-page house organ, Sept. 1950 issue of "Preiser News," features article on "Principle and Operation of the Electric Furnace"; includes section on new items for laboratories.—B. Preiser Co., Inc., 416 W. Washington St., Charleston 2, W. Va.

T-137 POLARIMETER. 2-page bulletin illustrates and describes English-made "Hilger M412" standard polarimeter and new "M417" small polarimeter.—The Jarrell Ash Co., 165 Newbury St., Boston, Mass.

T-138 BRIDGE OSCILLATOR. 8-page house organ, Vol. XXV, No. 7 issue of "The General Radio Experimenter," features articles on maker's "Type 1330-A" wide-frequency-range bridge oscillator, and toroidal dust-core inductors; discusses construction, mounting, comparison and specifications.—General Radio Co., 275 Mass. Ave., Cambridge 39, Mass.

T-139 ATMOSPHERE CONTROL. 4-page Catalog T623; (Sec. 1) features article on "Homocarb" atmosphere potential control.—Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Penna.

T-140 REMOTE AMPLIFIER. 4-page Form 2J4770 illustrates and describes maker's "BN-2A" portable remote amplifier; includes features and specifications.—Broadcast Equipment Section, RCA Engineering Products Dept., Camden, N. J.

T-141 FLOW CONTROL. 2-page Form 2250 illustrates and describes maker's raw green liquor control system.—The Foxboro Co., Foxboro, Mass.

T-142 ELECTROPHORESIS. 12-page Bulletin 2175 illustrates and describes maker's complete electrophoresis laboratory; covers range of application, sensitivity, features, optical system, control panel, temperature control, etc.—American Instrument Co., Silver Springs, Md.

T-143 TEMPERATURE RESEARCH AND TESTING UNITS. 4-page Bulletin S-950 illustrates and describes maker's "S-series" temperature-controlled chambers for research and testing; includes general data, specifications and temperature conversion table.—Refrigeration Div., Bowser Inc., Terryville, Conn.

T-144 OSCILLOSCOPE CAMERA. 18-page brochure of an address on maker's poleroid oscilloscope camera; includes illustrations and performance.—Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y.

E-145 RADIO EQUIPMENT. 100-page catalog features section on "The Home Music System" and a catalog section listing radio equipment.—Sun Radio and Electronics Co., Inc., 122-124 Duane St., New York 7, N. Y.

T-146 COLORIMETER. 4-page Publication CH-341 illustrates and describes English-made "Hilger" microptic colorimeter; covers data, glass scales and illumination.—The Jarrell Ash Co., 165 Newbury St., Boston, Mass.

T-147 ELECTROMAGNET. 4-page catalog illustrates and describes maker's electromagnet for research applications, includes characteristics.—Mechanical Div., Arthur D. Little, Inc., Cambridge 42, Mass.

T-148 PYROMETER EQUIPMENT. 8-page catalog GEA-5534 illustrates and describes maker's pyrometer equipment for indication and control of temperature and protection of heat-process equipment.—Apparatus Dep't, General Electric Co., Schenectady, N. Y.

T-149 TV VERTICAL-DEFLECTION AMPLIFIERS. 4-page AN-146, Dec. 1, 1950 issue of "RCA Application Note" features article on "Minimizing Pulse Voltages in Television Verti-

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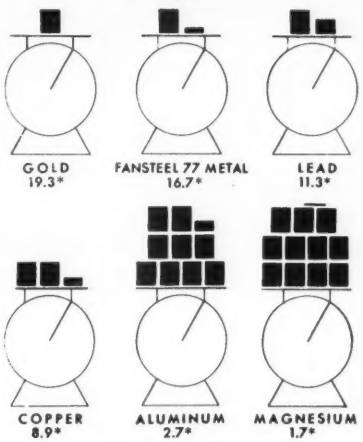

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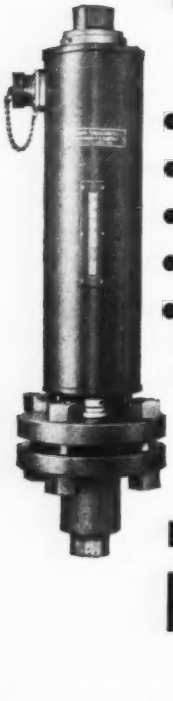

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T-150 IMPULSE COUNTER. 28-page house organ, No. 70 Winter issue of "Cenco News Chats," features articles on impulse counter, electropolisher, distillation-titration support and other laboratory equipment items.—Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill.

T-151 THERMOSTATS. 2-page catalog sheet illustrates and describes maker's "Type C" bimetal thermostats; includes application, principle, calibration and construction.—Stevens Manufacturing Co., Inc., Mansfield, Ohio.

T-152 THERMOCOUPLES. 24-page Catalog 12 illustrates and describes maker's thermocouple lead wires, heads, insulators and tubes.—Industrial Pyrometer & Supply Co., Alton, Ill.

T-153 RELAYS. 6-page Bulletin 681 illustrates and describes maker's "Nullmatic" multifunction relays; includes specifications on five models.—Moore Products Co., Philadelphia 24, Penna.

T-154 POWER SUPPLY. 2-page brochure describes and illustrates maker's "Model 500R" voltage-regulated power supply.—Kepco Laboratories, Inc., 149-14 41st Ave., Flushing, N. Y.

T-155 TRIODES. 2-page AN-147 Dec. 1, 1950 issue of "Application Note" features article on pencil-type triodes.—Tube Dep't, RCA, Harrison, N. J.

T-156 ULTRA-VIOLET PHOTOMETER. 2-page bulletin illustrates and describes English-made "Hilger" ultra-violet photometer and accessories.—The Jarrell Ash Co., 165 Newbury St., Boston, Mass.

T-157 BATTERIES. 2-page bulletin discusses five additional models of maker's light rechargeable batteries.—Yardney Electric Corp., 105-107 Chambers St., New York 7, N. Y.

T-158 POWER SUPPLY. 2-page brochure illustrates and describes maker's "Model 510" dual voltage-regulated power supply.—Kepco Laboratories Inc., 149-14, Forty-first Ave., Flushing, N. Y.

T-159 ALUMINUM TUBING. 8-page brochure illustrates and discusses the application of aluminum to the instrument industry; includes tables on mechanical properties, bursting pressures, conversion factors and thermal expansion.—Aluminum Company of America, Pittsburgh 19, Penna.

T-160 HYDROLOGICAL INSTRUMENTS. 4-page house organ No. 35, Dec. 1950 issue of "The Hydromike," includes article on proposed Tacoma, Wash. hydroelectric project.—Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Ore.

T-161 POWER SUPPLY. 2-page bulletin illustrates and describes maker's "Model 515" voltage-regulated power supply; lists specifications.—Kepco Laboratories, Inc., 149-14 Forty-first Ave., Flushing, N. Y.

T-162 PROCESSING BELTS. 4-page Bulletin 94 illustrates and describes maker's wire cloth processing belts; lists applications.—The Cambridge Wire Cloth Co., Cambridge, Md.

T-163 MOISTURE METER. 6-page Bulletin 1295 illustrates maker's "Midget" moisture meter for determining moisture content of wood and plaster.—Dep't 67, Tagliabue Instruments Div., Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N. J.

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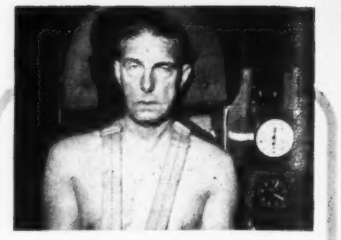

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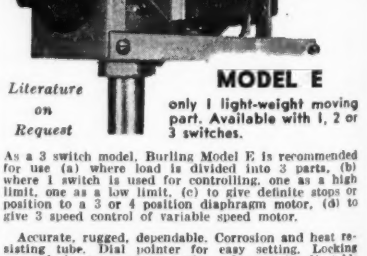

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T-164 SIGHT FEED BUBBLER AND SEDIMENT TRAP. 2-page Bulletin EX 285 illustrates and describes maker's sight feed bubbler and sediment trap; lists construction features, materials, pipe connections, filler plug, etc.—King Engineering Corp., Ann Arbor, Mich.

T-165 SPEED CONTROL VALVES. 4-page Bulletin 253 illustrates and describes maker's "Flo-set" speed control valves.—Hanna Engineering Works, 1765 Elston Ave., Chicago 22, Ill.

T-166 ELECTROMETER. 6-page bulletin illustrates and describes maker's "Model 361-20" electrometer; includes design features, applications, operating principle and accessories.—London Instruments, Inc., Chicago, Ill.

T-167 STRIP CHART RECORDER. 4-page Bulletin C2-2 illustrates and describes maker's "Capacilog" electronically-operated strip chart recorders; includes specifications, operation and price list.—Wheelco Instruments Co., Chicago 7, Ill.

T-168 RECORDING EQUIPMENT. 2-page brochure (Form 2J-6895) illustrates and describes maker's AM-FM and television professional recording equipment; includes technical information on recording.—Dep't 522, RCA Engineering Products, Camden 2, N. J.

T-169 ELECTRICAL FITTINGS. 12-page Catalog 1050 illustrates and describes maker's line of solderless wire connections, cable and conduit fittings and wiring devices; includes specifications, dimensional data and application instructions.—Buchanan Electrical Products Corp., 1290 Central Ave., Hillside, N. J.

T-170 DOSIMETER. 8-page Bulletin G-1 illustrates and describes maker's line of portable instruments for radiation protection; including dosimeter charger, low-range dosimeter, isotope analysis unit, etc.—Landsverk Electrometer Co., Pippin Road, Cincinnati 31, Ohio.

T-171 POWER SUPPLY. 2-page bulletin illustrates and describes maker's "Model 315" voltage-regulated power supply; includes specifications.—Kepco Laboratories, Inc., 149-14 Forty-first Ave., Flushing, N. Y.

T-172 RESISTORS. 2-page bulletin illustrates and describes maker's "Carbofilm" and "Baro-carbofilm" resistors.—Wilkor Products, Inc., 2882 Detroit Ave., Cleveland 13, Ohio.

T-173 MAGNETIC PIPELINE TRAP. 4-page Bulletin 202 illustrates and describes maker's magnetic pipeline trap for protection against Tramp iron.—Eriez Manufacturing Co., Erie, Penna.

T-174 CARBIDE TOOLS AND PARTS. 60-page catalog GT-250 illustrates and describes maker's line of tools, standard blanks, masonry drills and wheel dressers; includes technical data and applications.—Carboloy Co., Detroit 32, Mich.

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CONTENTS

EDITOR'S FOREWORD

AUTHOR'S PREFACE

CHAPTER I—ESSENTIAL TOOLS

CHAPTER II—D-C. INSTRUMENTS

Dismounting and Reassembling—KX-124 Instruments—DB-12 Instruments—Test and Inspection—Principles of Operation—Maintenance—Connections.

TROUBLE CHART FOR D-C. INSTRUMENTS

CHAPTER III—A-C. AMMETERS AND VOLTMETERS

Principles of Operation—Construction—Dismantling KA-24 Instrument—Reassembling—Dismantling DB-12 Instrument—Test and Inspection—Internal and External Connections—Maintenance.

CHAPTER IV—ELECTRODYNAMIC TYPE INSTRUMENTS

WATTMETERS—Construction—The KF-24 Wattmeter—The AB-12 Wattmeters—Connections—Principle of Operating—Inspection and Calibration—Single-phase Wattmeter—Polyphase Wattmeter—Maintenance.

FREQUENCY METERS—Construction—The KF-24 Instrument—The AB-12 Instrument—Principles of Operation—Test and inspection—Maintenance.

CHAPTER V—POWER FACTOR METERS AND SYNCHROSCOPES

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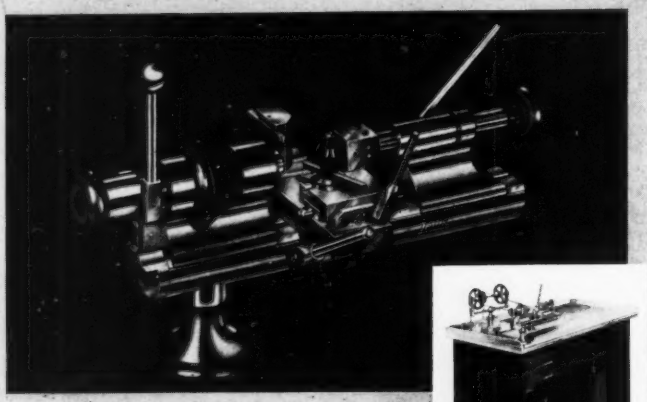

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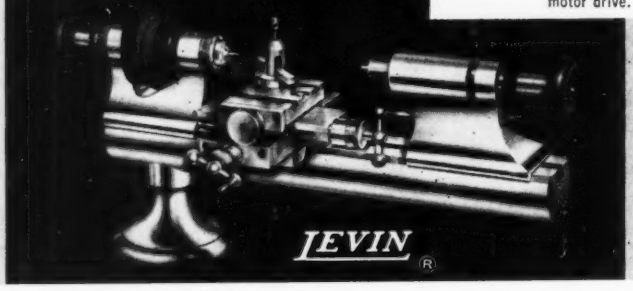

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T-177 BRIDGE OSCILLATOR. 8-page house organ, Vol. XXV, No. 7 issue of "The General Radio Experimenter," features article on maker's "Type 1330-A" wide-frequency-range bridge oscillator.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

T-178 BETA-GAMMA CHECKER. 4-page bulletin illustrates and describes maker's hand and foot checker for determining beta-gamma contamination on worker's hands and feet; discusses applications, maintenance and requirements.—The Austin Co., 19 Rector St., New York 6, N. Y.

T-179 TEMPERATURE CONTROLLER. 6-page Publication No. 1048-B illustrates and describes maker's "Model 191" electronic temperature controller designed for automatic operation of maintenance circuits.—Instrument Div., Thomas A. Edison, Inc., West Orange, N. J.

T-180 BOURDON GAGES. 16-page brochure discusses maker's bourdon gages; includes discussions on bourdon tubes, tube mounting, movement, linkage and calibration.—Heise Bourdon Tube Co., Newtown, Conn.

T-181 TAP SWITCHES. 2-page house organ, Dec. 1950 issue of "The Ohmite News", discusses and illustrates maker's "Model 111" tap switch and "Brown Devil" resistors.—Ohmite Manufacturing Co., 4835-41 Flourney St., Chicago 44, Ill.

T-182 TESTING MACHINES. 30-page Catalog RU-4-50 illustrates and describes maker's line of testing machines to 400,000 lbs. capacity; includes details of construction, specifications and dimensions.—Riehle Testing Machine Div., American Machine and Metals, Inc., East Moline, Ill.

T-183 LABORATORY APPARATUS. 16-page house organ, No. 51-1-41 issue of "Eberbach Announcer," illustrates and describes laboratory apparatus (high-vacuum pumps, blenders, blood gas apparatus, balances, etc.). Features article "The Scientific Instrument Industry—Key to America's Welfare and Economic Security."—Eberbach & Son Co., 200 E. Liberty St., Ann Arbor, Mich.

T-184 FEED WATER CONTROLLER. 16-page Bulletin 105-c illustrates and describes maker's 3-element, air-operated feed water controller; includes diagrams, cutaway views and chart records.—Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio.

T-185 DIRECT-WRITING RECORDERS. 16-pages, Bulletins 1, 2, 3, 3A, 4, 5 and 6 illustrate and describe maker's galvanometer "Model 51-500," recorder-assembly "Model 51-600T," amplifiers "Model 126 and 140," amplifier-recorder "Model 128" and twin recorder "Model 60."—Sanborn Company, Cambridge 39, Mass.

T-186 DIFFERENTIAL GAGES. 4-page Bulletin 1M50 illustrates and describes maker's "Series 400" recording and indicating differential gages; covers "ring balance" principle of operation, model type and selection chart, specifications, mounting dimensions.—Hagan Corporation, Hagan Bldg., Pittsburgh 30, Penna.

T-187 TEMPERATURE REGULATOR. 6-page bulletin describes and illustrates maker's electronic temperature regulator and regulator system for aircraft use; covers operation, applications, advantages.—AiResearch Mfg. Co., Div. of The Garrett Corp., Los Angeles 45, Calif.

T-188 HARDNESS TESTERS. 6-page folder illustrates and describes maker's portable hardness testers; covers specifications, features, operation; illustrates and describes accessory bench stand.—Ames Precision Machine Works, Waltham 54, Mass.

T-189 VACUUM-TUBE ELECTROMETER. 4-page bulletin describes and illustrates maker's "Model 200" vacuum-tube electrometer; covers features, specifications, uses and advantages.—Keithley Instruments, 1507 Warrensville Center Rd., Cleveland 21, Ohio.

T-190 SELECTOR SWITCHES. 2-page bulletin illustrates and describes maker's "Type 31-3" selector switches for electrical instrument cir-

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cuits and other applications; covers features, operation, specifications and electrical characteristics.—Leeds & Northrup Co., 4908 Stenton Ave., Philadelphia 44, Penna.

T-191 MECHANICAL FLOWMETERS. 12-page Bulletin 2M50 describes and illustrates maker's "Series 2200-2600" mechanical flowmeters; covers "ring balance" principle of operation and features for indicating, recording and integrating, indicating-recording and integrating, boiler steam flow-air flow, and dual models; also lists chart ranges and covers ring assemblies.—Hagan Corporation, Hagan Bldg., Pittsburgh 30, Penna.

T-192 JACKETED PIPE AND FITTINGS. 8-page Bulletin J-50 illustrates and describes maker's cast iron, cast or welded steel jacketed pipe and fittings for maintaining uniform temperatures in process pipes; covers dimensions, types; also describes pumps, and automatic valves with "Fluidometer" metering system.—Hetherington & Berner Inc., 701-745 Kentucky Ave., Indianapolis 7, Ind.

T-193 AUDIO TEST OSCILLATOR. 16-page Vol. 15, No. 12 issue of house organ, "The C-D Capacitor," features illustrated article titled "An Inexpensive, Variable-frequency Audio Test Oscillator," covers components, construction, adjustment and calibration; also includes regular feature "The Radio Trading Post—A Free Market-place for Buyers, Sellers, and Swappers."—Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

T-194 RECORDING OSCILLOGRAPH. 4-page Vol. 31, No. 1, issue of house organ, "The Bodine Motorgram," features article on Consolidated recording oscillograph and application of maker's motor in chart or film drive system; also lists copies available of maker's "Chief Engineer's Notebook" on motor applications.—Bodine Electric Co., 2250 W. Ohio St., Chicago 12, Ill.

T-195 RELAY CATALOG. 24-page Catalog 109 describes and illu trates maker's line of relays; covers features, applications, capacities, enclosures, ordering information; also covers shaded-pole motors, synchronous timers and signals.—Potter & Brumfield, Princeton, Ind.

T-196 ORIFICE AND NOZZLE CAPACITY DATA. 12-page Bulletin T-100-M titled "Capacity Data for Concentric Orifices and Flow Nozzles" presents method for approximating orifice or nozzle throat to pipe diameter ratios required for fluid meter installations.—Hagan Corporation, Hagan Bldg., Pittsburgh 30, Penna.

T-197 RECOOLING SPRAY NOZZLE SYSTEMS. 8-page Bulletin Supplement 6A-SP describes and illustrates maker's recooling spray nozzle systems; covers design, application, construction and operation of nozzles; also diagrams typical spray-pond arrangements.—Dep't J-D, Schutte & Koerting Co., Cornwells Heights, Bucks County, Penna.

T-198 AIRCRAFT THERMOMETER TESTERS. 2-page bulletin illustrates and describes maker's instruments for thermocouple or resistance testing of aircraft temperature indicators; covers features, ranges and operation.—The Lewis Engineering Co., Naugatuck, Conn.

T-199 COMBUSTION CONTROL. 5 bulletins (case histories) on use of maker's combustion control equipment include applications in (1) a bag manufacturing plant, (2) a food processing plant, (3) a rubber processing plant, (4) a cigarette factory, and (5) a paint plant. Each bulletin includes description of problems, existing conditions, control system operation, and results from installation.—The Hays Corp., Michigan City, Ind.

T-200 CONTOUR PROJECTOR. 8-page bulletin illustrates and describes maker's "Model 2" contour projector for light-beam magnification and measurement of dimensions, shapes and surfaces; covers features, operation, construction, accessories, dimensions and specifications.—Industrial Optical Sales Div., Eastman Kodak Co., Rochester 4, N. Y.

T-201 FLUID FLOW-RATE TESTING. 20-page Technical Bulletin A-9C-4 contains comprehensive data on technical developments on fluid flow-rate testing for aircraft engines and accessories; covers engineering principles, flow curves and charts, calibration techniques and calibration panels.—Fischer & Porter Co., 3780 County Line Rd., Hatboro, Penna.

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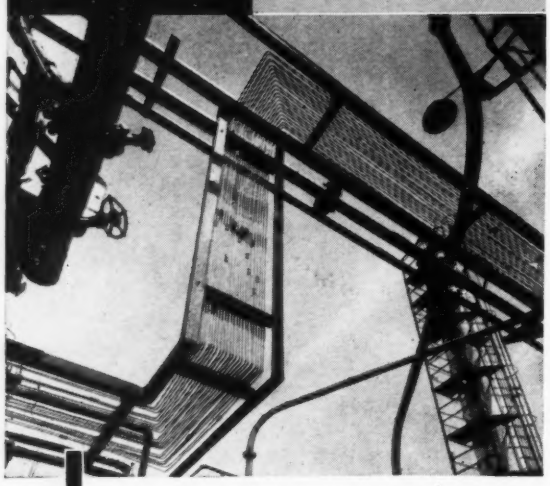

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ADVERTISERS' INDEX

Acragage Company 208
Allied Radio Corp. 177
Aluminum Co. of America 240
American Chain & Cable Co. 185
American Chronoscope Corporation 190
American Meter Co. 138-139
American Time Products, Inc. 142
Ampex Electric Corp. 202
Amthor Testing Instrument Co. 206
Annin Company 127
Arma Corp. 126
Arnold Engineering Co. 136
Askania Regulator Co. 228
Atlas Valve Company 173

Bailey Meter Co. 134
Barksdale Valves 165
Barton Instrument Corp. 169
Bendix Aviation Corp. 187, 199
Berkeley Scientific Co. 204
Black, Sivalls & Bryson, Inc. 227
Borg Corporation, George W. 196-197
Bristol Co. 147
Brush Development Co. 143
Burling Instrument Co. 236
Burlington Instrument Co. 202

Cambridge Instrument Co., Inc. 166
Carboloy Company, Inc. 121-125
Century Geophysical Corp. 195, 239
Cerro de Pasco Copper Corp. 226
Chace Co., W. M. 189
Chatillon & Sons, John 149
Clare & Co., C. P. 148
Conn Ltd., C. G. 188
Conoflow Corp. 176
Consolidated Engineering Corp. 193

Dial Light Company of America 170
Distillation Products Industries 140

Eagle Signal Corp. 166
Eclipse-Pioneer Div., Bendix 187
Electric Auto-Lite Co. 208
Electro Products Laboratories 173
Emery Company, A. H. 192
Eppley Laboratory, Inc. 174

Fairchild Camera & Instrument Corp. 164
Falstrom Co. 120
Fansteel Metallurgical Corporation 235
Farris Stacon Corp. 168
Fisher Governor Co. 150
Friez Instrument Div., Bendix 199

Gaertner Scientific Corp. 186
Gamma Scientific Company 199
General Electric Co. 141, 165
General Radio Co. 117
Giannini & Co., Inc., G. M. 236
G-M Laboratories, Inc. 235
Gordon Co., Claud S. 234
Green Instrument Co. 194
Guardian Electric Mfg. Co. 144

Hagan Corp. 183
Hammel-Dahl Co. ..... Inside Back Cover
Hastings Instrument Co., Inc. 186
Hathaway Instrument Co. 190
Hays Corp. 130
Heiland Research Corp. 205
Heise Bourdon Tube Co. 206
Helicoid Gage Div. 185
Hellige, Inc. 194
Hexacon Electric Co. 204
Hycor Company, Inc. 192

Illinois Testing Laboratories, Inc. 181
Industrial Div., Minneapolis-Honeywell Regulator Co. 137, 178-179, 233

Jerguson Gage & Valve Co. 196

Kemp Mfg. Co., C. M. 175
Kieley & Mueller, Inc. 135
Kirk & Blum Mfg. Co. 226

Leeds & Northrup Co. 152
Leslie Co. 132
Levin & Son, Inc., Louis 238
Lewis Engineering Co. 121
L & R Manufacturing Co. 168

Manning, Maxwell & Moore, Inc. 163
Marsh Instrument Co. 164
Marshalltown Mfg. Co. 175
Measurements Corp. 201
Mercoid Corp. 204
Meriam Instrument Co. 167
Mico Instrument Co. 208
Midwestern Geophysical Laboratory 200
Minneapolis-Honeywell Regulator Co. 137, 178-179, 233
Moeller Instrument Co. 162

New Hermes, Inc. 202

Optical Film Engineering Co. 171
Oster Mfg. Co., John 239

Precision Thermometer & Instrument Co. 236
Pyrometer Instrument Co. 235

Rochester Mfg. Co., Inc. 177
Rockwell Co., W. S. 188
Rockwell Mfg. Co. 207

Sc[illegible]s Corp. of America 131
Seth Thomas Clock Co. 197
Shallcross Mfg. Co. 171
Shore Instrument & Mfg. Co. 196
Simpson Electric Co. 165
Sola Electric Co. .....Back Cover
Sorensen & Co., Inc. 146
Standard Electric Time Co. 205
Standard Products Inc. 196
Statham Laboratories 170
Superior Electric Co. 118-119
Superior Tube Co. 145

TAGliabue Instruments Div., Weston Electrical Instrument Corp. Inside Front Cover
Taylor Instrument Companies 122-123
Techno Instrument Company 184
Tenney Engineering, Inc. 191
Thomas & Skinner Steel Products Co. 201
Trerice Co., H. O. 172
Trimount Instrument Co. 174
Triplett Electrical Instrument Co. 151

Uehling Instrument Co. 192
Unertl Optical Co., John 206

Wallace & Tiernan Products, Inc. 133
Waterman Products Co., Inc. 182
Weston Electrical Instrument Corp. (TAGliabue Instruments Div.) Inside Front Cover
Wheatstone Corporation 184
Wheelco Instruments Co. 128-129
White Dental Mfg. Co., S. S. 194

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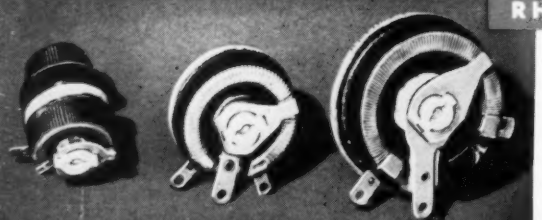

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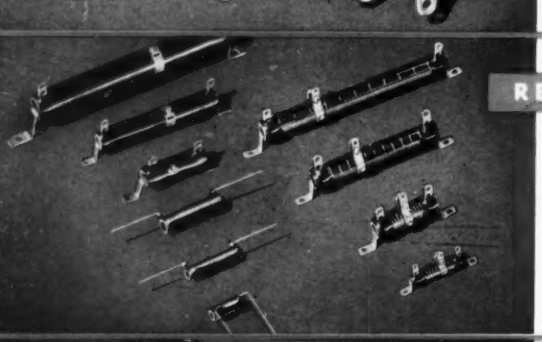

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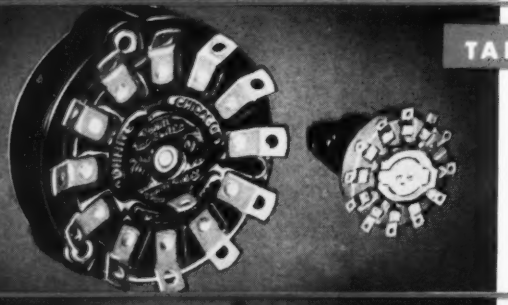

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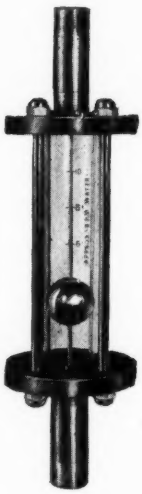
SK ENGINEERING News

Low-Cost Flow Indicators Assist In Close Process Control

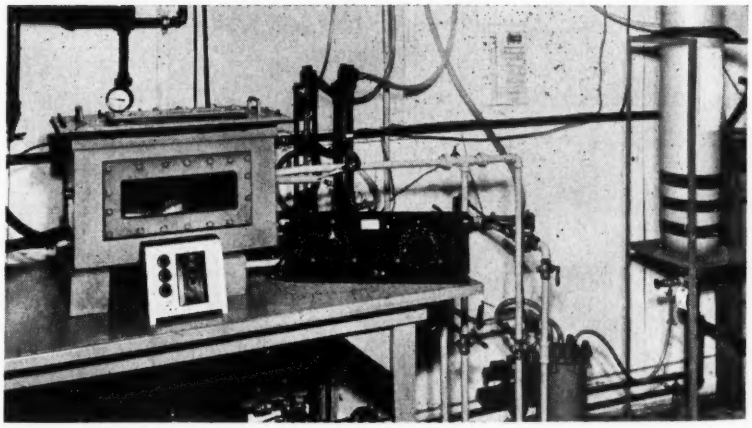
Ball Flow Indicators, a stock item, are typical of the many types of flow indicators designed by SK to permit visual inspection of flow in a pipe line. Very reasonable in cost, their use provides the necessary positive knowledge of flow conditions to insure proper control, thus conserving power, saving costly batches, insuring continuous process operation and preventing damage to expensive equipment.



The SK Ball Flow Indicator illustrated provides both a visual indication of flow and the approximate rate of flow. A moving brass ball acts as the indicator, and neoprene gaskets are used to seal the glass tube—permitting this type indicator to be used with lubricating oils and many solvents.

You, too, might profit, as many have, by using flow indicators in your operations. *Send for details.*

SK ROTAMETERS CONTROL FLOW IN NEW GAS PLATING PROCESS



A new gas plating process under development at Commonwealth Engineering Company of Ohio utilizes the volatility and decomposition characteristics of certain metallic compounds such as carbonyls, nitrosyls, hydrides, salts, and metal organics to plate both metallic and non-metallic materials. Results of this process are similar in many respects to those obtained by electroplating, however, gas plating permits the plating of non-conductors of electricity such as paper, plastics, tile and other non-metallic materials.

In this new process, SK Rotameters play an important role. In the pilot set-up shown above, one SK Fig. 1891 Universal Rotameter is used to control the flow of carrier gas, usually carbon dioxide, while another is used to control the flow of nickel carbonyl-carrier gas mixture as it comes from a carburetor. Since the ratio between the nickel carbonyl and the carrier gas determines, to a considerable degree, the character of the films deposited, the importance of providing such accurate flow measurement can be realized.

SK Universal Rotameters are available from stock. *For detailed information, write for Bulletin* 18-*RB.*

NEW USE FOR ROTAMETERS

New uses for SK Rotameters are constantly developing. One of the most unique and distinctive applications is the recent use of a Rotameter for measuring blood in connection with experiments on an artificial kidney and an artificial heart. The Rotameter acts as an accurate metering device and makes it possible to utilize whole blood without coagulation. It was surprisingly noted during experiments that the viscosity of the blood is not too appreciable and is variable depending on whether a man's or woman's blood was used.

Possibly you can use a Rotameter application in your operation, too. *Ask for Bulletin* 18-*RA—it gives you a brief description and application of all standard SK Rotameters and briefly describes complete bulletins on all types.*

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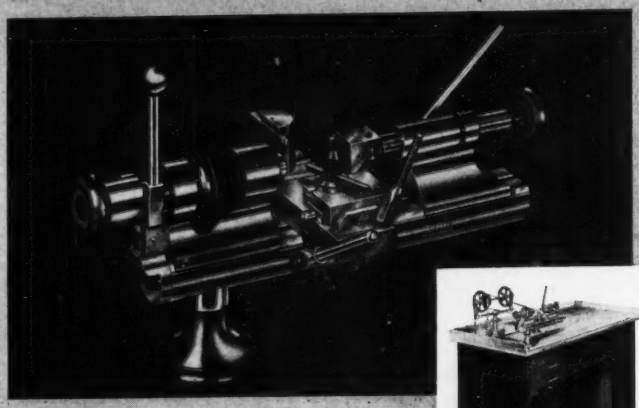

A *LEVIN* lathe makes delicate precision easy because it is designed for working with small parts. Collets from .004" to 5/16" are standard and kept in stock. Two sizes of lathes with maximum collet capacity either 3/16" or 5/16", swing 4", bed length 12". Full line of accessories for second operations, production, tool work and model making. Send for catalog.

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COMPLETE CATALOG illustrates and describes full line of accessories . . . compound slide rests, grinding, milling and screw cutting attachments, cross slide, collet closer and other useful items.

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search and laboratory use (electrocardiogram, phonocardiogram, pneumogram and ballistocardiogram, etc.).—Sanborn Co., Cambridge 39, Mass.

T-177 BRIDGE OSCILLATOR. 8-page house organ, Vol. XXV, No. 7 issue of "The General Radio Experimenter," features article on maker's "Type 1330-A" wide-frequency-range bridge oscillator.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

T-178 BETA-GAMMA CHECKER. 4-page bulletin illustrates and describes maker's hand and foot checker for determining beta-gamma contamination on worker's hands and feet; discusses applications, maintenance and requirements.—The Austin Co., 19 Rector St., New York 6, N. Y.

T-179 TEMPERATURE CONTROLLER. 6-page Publication No. 1048-B illustrates and describes maker's "Model 191" electronic temperature controller designed for automatic operation of maintenance circuits.—Instrument Div., Thomas A. Edison, Inc., West Orange, N. J.

T-180 BOURDON GAGES. 16-page brochure discusses maker's bourdon gages; includes discussions on bourdon tubes, tube mounting, movement, linkage and calibration.—Heise Bourdon Tube Co., Newtown, Conn.

T-181 TAP SWITCHES. 2-page house organ, Dec. 1950 issue of "The Ohmite News", discusses and illustrates maker's "Model 111" tap switch and "Brown Devil" resistors.—Ohmite Manufacturing Co., 4835-41 Flourney St., Chicago 44, Ill.

T-182 TESTING MACHINES. 30-page Catalog RU-4-50 illustrates and describes maker's line of testing machines to 400,000 lbs. capacity; includes details of construction, specifications and dimensions.—Riehle Testing Machine Div., American Machine and Metals, Inc., East Moline, Ill.

T-183 LABORATORY APPARATUS. 16-page house organ, No. 51-1-41 issue of "Eberbach Announcer," illustrates and describes laboratory apparatus (high-vacuum pumps, blenders, blood gas apparatus, balances, etc.). Features article "The Scientific Instrument Industry—Key to America's Welfare and Economic Security."—Eberbach & Son Co., 200 E. Liberty St., Ann Arbor, Mich.

T-184 FEED WATER CONTROLLER. 16-page Bulletin 105-c illustrates and describes maker's 3-element, air-operated feed water controller; includes diagrams, cutaway views and chart records.—Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio.

T-185 DIRECT-WRITING RECORDERS. 16-pages, Bulletins 1, 2, 3, 3A, 4, 5 and 6 illustrate and describe maker's galvanometer "Model 51-500," recorder-assembly "Model 51-600T," amplifiers "Model 126 and 140," amplifier-recorder "Model 128" and twin recorder "Model 60."—Sanborn Company, Cambridge 39, Mass.

T-186 DIFFERENTIAL GAGES. 4-page Bulletin 1M50 illustrates and describes maker's "Series 400" recording and indicating differential gages; covers "ring balance" principle of operation, model type and selection chart, specifications, mounting dimensions.—Hagan Corporation, Hagan Bldg., Pittsburgh 30, Penna.

T-187 TEMPERATURE REGULATOR. 6-page bulletin describes and illustrates maker's electronic temperature regulator and regulator system for aircraft use; covers operation, applications, advantages.—AiResearch Mfg. Co., Div. of The Garrett Corp., Los Angeles 45, Calif.

T-188 HARDNESS TESTERS. 6-page folder illustrates and describes maker's portable hardness testers; covers specifications, features, operation; illustrates and describes accessory bench stand.—Ames Precision Machine Works, Waltham 54, Mass.

T-189 VACUUM-TUBE ELECTROMETER. 4-page bulletin describes and illustrates maker's "Model 200" vacuum-tube electrometer; covers features, specifications, uses and advantages.—Keithley Instruments, 1507 Warrensville Center Rd., Cleveland 21, Ohio.

T-190 SELECTOR SWITCHES. 2-page bulletin illustrates and describes maker's "Type 31-3" selector switches for electrical instrument cir-

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T-191 MECHANICAL FLOWMETERS. 12-page Bulletin 2M50 describes and illustrates maker's "Series 2200-2600" mechanical flowmeters; covers "ring balance" principle of operation and features for indicating, recording and integrating, indicating-recording and integrating, boiler steam flow-air flow, and dual models; also lists chart ranges and covers ring assemblies.—Hagan Corporation, Hagan Bldg., Pittsburgh 30, Penna.

T-192 JACKETED PIPE AND FITTINGS. 8-page Bulletin J-50 illustrates and describes maker's cast iron, cast or welded steel jacketed pipe and fittings for maintaining uniform temperatures in process pipes; covers dimensions, types; also describes pumps, and automatic valves with "Fluidometer" metering system.—Hetherington & Berner Inc., 701-745 Kentucky Ave., Indianapolis 7, Ind.

T-193 AUDIO TEST OSCILLATOR. 16-page Vol. 15, No. 12 issue of house organ, "The C-D Capacitor," features illustrated article titled "An Inexpensive, Variable-frequency Audio Test Oscillator," covers components, construction, adjustment and calibration; also includes regular feature "The Radio Trading Post—A Free Market-place for Buyers, Sellers, and Swappers."—Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

T-194 RECORDING OSCILLOGRAPH. 4-page Vol. 31, No. 1, issue of house organ, "The Bodine Motorgram," features article on Consolidated recording oscillograph and application of maker's motor in chart or film drive system; also lists copies available of maker's "Chief Engineer's Notebook" on motor applications.—Bodine Electric Co., 2250 W. Ohio St., Chicago 12, Ill.

T-195 RELAY CATALOG. 24-page Catalog 109 describes and illustrates maker's line of relays; covers features, applications, capacities, enclosures, ordering information; also covers shaded-pole motors, synchronous timers and signals.—Potter & Brumfield, Princeton, Ind.

T-196 ORIFICE AND NOZZLE CAPACITY DATA. 12-page Bulletin T-100-M titled "Capacity Data for Concentric Orifices and Flow Nozzles" presents method for approximating orifice or nozzle throat to pipe diameter ratios required for fluid meter installations.—Hagan Corporation, Hagan Bldg., Pittsburgh 30, Penna.

T-197 RECOOLING SPRAY NOZZLE SYSTEMS. 8-page Bulletin Supplement 6A-SP describes and illustrates maker's recooling spray nozzle systems; covers design, application, construction and operation of nozzles; also diagrams typical spray-pond arrangements.—Dep't J-D, Schutte & Koerting Co., Cornwells Heights, Bucks County, Penna.

T-198 AIRCRAFT THERMOMETER TESTERS. 2-page bulletin illustrates and describes maker's instruments for thermocouple or resistance testing of aircraft temperature indicators; covers features, ranges and operation.—The Lewis Engineering Co., Naugatuck, Conn.

T-199 COMBUSTION CONTROL. 5 bulletins (case histories) on use of maker's combustion control equipment include applications in (1) a bag manufacturing plant, (2) a food processing plant, (3) a rubber processing plant, (4) a cigarette factory, and (5) a paint plant. Each bulletin includes description of problems, existing conditions, control system operation, and results from installation.—The Hays Corp., Michigan City, Ind.

T-200 CONTOUR PROJECTOR. 8-page bulletin illustrates and describes maker's "Model 2" contour projector for light-beam magnification and measurement of dimensions, shapes and surfaces; covers features, operation, construction, accessories, dimensions and specifications.—Industrial Optical Sales Div., Eastman Kodak Co., Rochester 4, N. Y.

T-201 FLUID FLOW-RATE TESTING. 20-page Technical Bulletin A-9C-4 contains comprehensive data on technical developments on fluid flow-rate testing for aircraft engines and accessories; covers engineering principles, flow curves and charts, calibration techniques and calibration panels.—Fischer & Porter Co., 3780 County Line Rd., Hatboro, Penna.

Century
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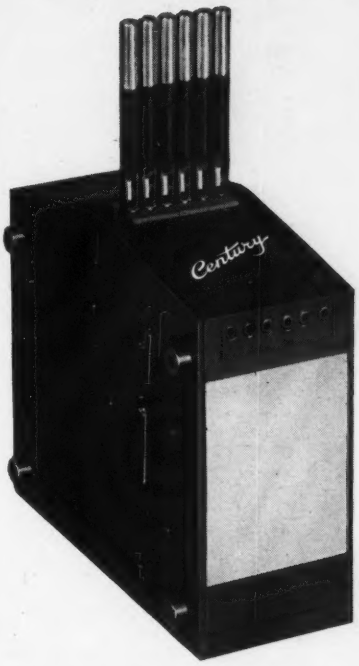
GALVANOMETERS



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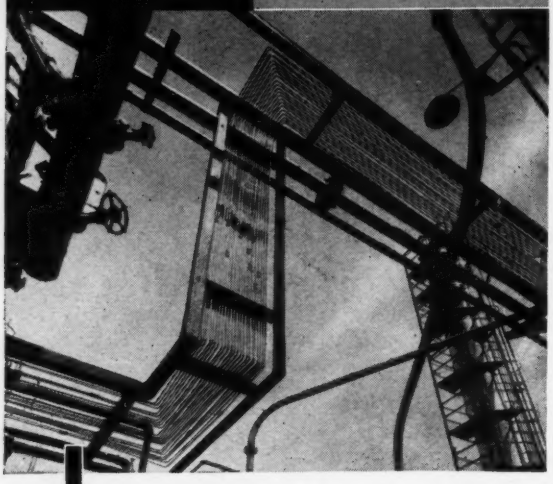

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ADVERTISERS' INDEX

Acragage Company 208
Allied Radio Corp. 177
Aluminum Co. of America ... 240
American Chain & Cable Co. 185
American Chronoscope Corporation 190
American Meter Co. 138-139
American Time Products, Inc. 142
Ampex Electric Corp. 202
Amthor Testing Instrument Co. 206
Annin Company 127
Arma Corp. 126
Arnold Engineering Co. 136
Askania Regulator Co. 228
Atlas Valve Company 173

Bailey Meter Co. 134
Barksdale Valves 165
Barton Instrument Corp. 169
Bendix Aviation Corp. 187, 199
Berkeley Scientific Co. 204
Black, Sivalls & Bryson, Inc. 227
Borg Corporation, George W. 196-197
Bristol Co. 147
Brush Development Co. 143
Burling Instrument Co. 236
Burlington Instrument Co. 202

Cambridge Instrument Co., Inc. 166
Carboloy Company, Inc. 124-125
Century Geophysical Corp. 195, 239
Cerro de Pasco Copper Corp. 226
Chace Co., W. M. 189
Chatillon & Sons, John 149
Clare & Co., C. P. 148
Conn Ltd., C. G. 188
Conoflow Corp. 176
Consolidated Engineering Corp. 193

Dial Light Company of America 170
Distillation Products Industries 140

Eagle Signal Corp. 166
Eclipse-Pioneer Div., Bendix 187
Electric Auto-Lite Co. 208
Electro Products Laboratories 173
Emery Company, A. H. 192
Eppley Laboratory, Inc. 174

Fairchild Camera & Instrument Corp. 164
Falstrom Co. 120
Fansteel Metallurgical Corporation 235
Farris Stacon Corp. 168
Fisher Governor Co. 150
Friez Instrument Div., Bendix 199

Gaertner Scientific Corp. 186
Gamma Scientific Company 199
General Electric Co. 141, 165
General Radio Co. 117
Giannini & Co., Inc., G. M. 236
G-M Laboratories, Inc. 235
Gordon Co., Claud S. 234
Green Instrument Co. 194
Guardian Electric Mfg. Co. 144

Hagan Corp. 183
Hammel-Dahl Co. ..... Inside Back Cover
Hastings Instrument Co., Inc. 186
Hathaway Instrument Co. ... 150
Hays Corp. 130
Heiland Research Corp. 205
Heise Bourdon Tube Co. 205
Helicoid Gage Div. 185
Hellige, Inc. 194
Hexacon Electric Co. 204
Hycor Company, Inc. 192

Illinois Testing Laboratories, Inc. 181
Industrial Div., Minneapolis-Honeywell Regulator Co. 137, 178-179, 233

Jerguson Gage & Valve Co. 190

Kemp Mfg. Co., C. M. 175
Kieley & Mueller, Inc. 135
Kirk & Blum Mfg. Co. 226

Leeds & Northrup Co. 152
Leslie Co. 132
Levin & Son, Inc., Louis 238
Lewis Engineering Co. 121
L & R Manufacturing Co. 160

Manning, Maxwell & Moore, Inc. 163
Marsh Instrument Co. 164
Marshalltown Mfg. Co. 175
Measurements Corp. 201
Mercoid Corp. 201
Meriam Instrument Co. 167
Mico Instrument Co. 208
Midwestern Geophysical Laboratory 200
Minneapolis-Honeywell Regulator Co. 137, 178-179, 233
Moeller Instrument Co. 162

New Hermes, Inc. 202

Optical Film Engineering Co. 171
Oster Mfg. Co., John 239

Precision Thermometer & Instrument Co. 236
Pyrometer Instrument Co. 235

Rochester Mfg. Co., Inc. 177
Rockwell Co., W. S. 188
Rockwell Mfg. Co. 207

Selas Corp. of America 131
Seth Thomas Clock Co. 197
Shallcross Mfg. Co. 171
Shore Instrument & Mfg. Co. 196
Simpson Electric Co. 165
Sola Electric Co. ..... Back Cover
Sorensen & Co., Inc. 146
Standard Electric Time Co. 205
Standard Products Inc. 196
Statham Laboratories 170
Superior Electric Co. 118-119
Superior Tube Co. 145

TAGliabue Instruments Div., Weston Electrical Instrument Corp. Inside Front Cover
Taylor Instrument Companies 122-123
Techno Instrument Company 184
Tenney Engineering, Inc. 191
Thomas & Skinner Steel Products Co. 201
Trerice Co., H. O. 172
Trimount Instrument Co. 174
Triplett Electrical Instrument Co. 151

Uehling Instrument Co. 192
Unertl Optical Co., John 206

Wallace & Tiernan Products, Inc. 133
Waterman Products Co., Inc. 182
Weston Electrical Instrument Corp. (TAGliabue Instruments Div.) Inside Front Cover
Wheatstone Corporation 184
Wheelco Instruments Co. 128-129
White Dental Mfg. Co., S. S. 194